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Status of the Foothill yellow-legged frog (*Rana boylii*) in Oregon

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Aaron N. Borisenko and Marc P. Hayes

Abstract: Roughly 100 presumed historic localities for the foothill yellow-legged frog (*Rana boylii*) were obtained from an extensive search of verifiable sources. This pool yielded a subset of 90 identifiable localities that could be surveyed. Surveys, conducted in 1997-1998, coupled searches for frogs with the scoring or measurement and recording of biotic and physical variables. Surveys of localities lacking frogs (LLF) were repeated up to two times to ensure a high probability of detection and allow error estimation. Data collected were designed to facilitate comparison between localities with frogs (LWF) and LLF to reveal potential causes of disappearances.

In over 3,000 person-hours of survey effort, foothill yellow-legged frogs were found at 43.3% (39 of 90) of the localities surveyed. Localities with frogs differed significantly in substrate features, disturbance regimes, and their exotic vertebrate species compositions from LLF. Two substrate differences were significant: LWF had a coarser substrate and were less embedded than LLF. Likewise, two elements of human-related disturbance were prominent: LWF had significantly less grazing than the LLF, and most sites downstream from large impoundments were LLF. Exotic aquatic vertebrate species (bullfrogs and fishes) were observed significantly more often at LLF.

Foothill yellow-legged frogs may no longer exist at at least 55% of the localities at which they were historically recorded in Oregon. Physical and biotic data suggest that the LLF have sustained changes unfavorable to yellow-legged frogs, and that the pattern of change is complex. Prominent among physical changes was increased embeddenedness, a change that occurs because bedload fines increase. Several human-related disturbance factors can contribute to increasing bedload fines, and the relative importance of these factors may be drainage-specific. Distinguishing which factors are most important is a considerable task, but two factors known to frequently increase fine bedloading, grazing and impoundments, may play a prominent role because their distribution between LWF and LWF appeared to be strongly asymmetric. Interpretation of the importance of exotic aquatic vertebrates remains ambiguous. In particular, these data cannot disentangle extirpation of the foothill yellow-legged frog that has resulted from unfavorable habitat changes that simply favored the exotics from the potentially direct effects of exotics on foothill yellow-legged frogs via predation, competition, or some combination of these.

Introduction

Amphibian declines or disappearances have become prominent issues in conservation since the late 1980s (Blaustein and Wake 1990; Blaustein and Olson 1991; Blaustein et al 1994; Blaustein 1994). The Pacific Northwest (PNW) and the state of Oregon have not eluded this pattern, as various investigators have voiced concern and expressed the need to study vulnerable PNW amphibians (e.g., Blaustein et al. 1994, Bury and Corn 1988). However, where significant analyses have been done, they have been largely restricted to species that reproduce in stillwater, like the northern red-legged frog (*Rana aurora aurora*; Kiesecker and Blaustein 1997, 1998), the Oregon spotted frog (*Rana pretiosa*; Hayes 1997) and the Cascades frog (*Rana cascadae*; Fellers and Drost 1993). Although the basis of this bias is unclear, it may result from the disproportionately large representation of stillwater species in the amphibian fauna as well as the ease with which these amphibians can be studied. Regardless, species that use streams for reproduction are at least as vulnerable (Bury and Corn 1988, 1991), so a significant opportunity presented itself with the potentially vulnerable (Lind et al. 1996), stream-breeding foothill yellow-legged frog (*Rana boylii*).

The foothill yellow-legged frog is a relatively small ranid frog that is typically found close to water along open, low-gradient, streams dominated by a coarse substrate (Storer 1925; Fitch 1936, 1938; Zweifel 1955; Moyle 1973; Nussbaum et al. 1983; Hayes and Jennings 1988; Jennings and Hayes 1994; Kupferberg 1996a, 1996b; Lind et al. 1996). Restricted to Pacific drainages ranging from southern California (Storer 1923, 1925; Zweifel 1955; Moyle 1973; Hayes and Jennings 1988; Jennings and Hayes 1994) to Oregon (Fitch 1936, 1938; Gordon 1939; Zweifel 1955; Nussbaum et al. 1983) and a single disjunct record for Baja California, Mexico (Loomis 1965), verifiable records for the foothill yellow-legged frog in Oregon extend from the Winchuck River (OSU 4917)[1] in the extreme southwest corner of the state, eastward to the Klamath River (MVZ 17173), and north to the North Santiam River (OSU 1665).

Among western North American ranid frogs, the foothill yellow-legged frog is unique in showing a relatively rheophilic life history (Zweifel 1955; Stebbins 1951, 1985; Jennings and Hayes 1994), which, until relatively recently, had been little studied beyond its basic features (see Storer 1925, Fitch 1936, Stebbins 1951, Zweifel 1955, Moyle 1973). Over the last seven years, much effort has been devoted to understanding the interacting factors that influence yellow-legged frog life history (Fuller and Lind 1992, Lind et al. 1996, Van Wagner 1996, Welsh and Ollivier 1998), but particularly as the result of the elegant work of Kupferberg (1996a, 1996b, 1997a, 1997b) in the Eel River system (California). Active from March to October, observations have shown that foothill yellow-legged frogs emerge from overwintering locations some time after high spring flows (Storer 1925, Kupferberg 1996a), when water temperatures reach ca. 7°C (Zweifel 1955, Van Wagner 1996). The species appears to be flow-velocity sensitive, a condition that has been deduced from the correlation between oviposition and falling hydrographs (Storer 1925; Kupferberg 1996a, 1996b). Oviposition, which has been recorded in the late March-June interval (Storer 1925, Fitch 1936, Stebbins 1951, Zweifel 1955, Fuller and Lind 1992, Lind et al. 1996, Van Wagner 1996), occurs where low (≤ 6 cm/sec) flow velocities exist (Storer 1925; Kupferberg 1996a, 1996b). Behavioral details of the reproductive ecology of foothill yellow-legged frogs are largely unknown, but males adopt submerged calling stations near known egg-laying sites (MacTague and Northern 1993, Van Wagner 1996). Details of interactions leading to amplexus are unknown. Amplectic frogs have been observed both during the day and at night, but observations are too few to define patterns (Van Wagner 1996). After an interval of unknown length in amplexus, females typically deposit eggs as a single grape-like mass that contains about 500 to 1000 eggs on a solid substrate in low velocity water (Storer 1925, Fitch 1936, Zweifel 1955, Fuller and Lind 1992, Lind et al. 1996). This mode of oviposition results in coarse-substrate bars, where low velocity laminar flow over cobbles and boulders is a frequent phenomenon, frequently being the preferred sites for oviposition (Storer 1925, Fitch 1936, Stebbins 1951, Zweifel 1955, Fuller and Lind 1992, Lind et al. 1996). Factors that may conflict in the selection of oviposition sites have received limited study. Flow levels may have to be sufficient for adequate oxygenation to penetrate the relatively stiff egg masses of *Rana boylii*. Alternatively, flow likely has to be consistently low enough to prevent scour because high water events present a significant risk (Lind et al. 1996; Kupferberg 1996a, 1996b; Van Wagner 1996).

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[1] Specimens vouchering selected localities are indicated in parentheses following the locality noted. Notations indicate museum symbolic codes (Leviton et al. 1985) followed by the museum collection number of the voucher specimen.

Development and growth are only sketchily understood, and most data on this species are the result of studies in California. Embryos hatch in five days to a month, which appears to depend largely on water temperature (Zweifel 1955, Kupferberg 1996a). Larvae graze preferentially on epiphytic diatoms (Kupferberg 1996a, 1997a), which both facilitates the production of periphytal algal in their nursery streams and may be linked to key aspects of their nutritional requirements (Kupferberg 1996a, Malfatti 1996). Young larvae appear to occupy low flow backwaters that may behave as nursery areas over early development (Kupferberg 1996a), areas that geomorphologically are strongly linked to coarse-substrate bars (F. Ligon, pers. comm.). Larvae grow rapidly and metamorphose at a relatively small body size (22-27 mm snout-urostyle length [SUL]) in three to four months (Storer 1925, Zweifel 1955), and probably never overwinter. After metamorphosis, at least one study showed marked upstream movement (Twitty et al. 1967) similar to drift compensation seen in recently metamorphosed stream insects. However, a second study was unable to identify a clear pattern (Van Wagner 1996), so the significance of the earlier observation is vague. Foothill yellow-legged frogs have highly variable growth that may depend largely on how early in the year metamorphosis took place and food levels. Postmetamorphs may eat aquatic and terrestrial insects, but dietary data for yellow-legged frogs are sparse (see Storer 1925, Fitch 1936). In northwestern California (Van Wagner 1996), many frogs attained adult size during the fall of the year in which they developed from eggs. Males, which can exhibit secondary sexual features at body sizes as small as 32 mm SUL, are large enough to reproduce in the breeding season after the year they were laid as eggs (Van Wagner 1996). Based on the same study, some females attain a large enough body size fast enough to do the same thing, but most females seem to delay reproduction until year two. Longevity is unknown; only one frog (a female) in the only demographic study of this species was determined to be three or more years old (Van Wagner 1996). Age-specific sexual dimorphism is female-biased (Zweifel 1955, Van Wagner 1996); females attain a maximum body size of 82 mm SUL, but males reach only a 65 mm SUL maximum (M. Hayes, pers. observ.).

Behavior of the later life stages of the foothill yellow-legged frog remains relatively poorly understood. Juveniles and males have been recorded as making the longest movements (Van Wagner 1996), but the context is vague. Greater frequency of oviposition on bars close to tributary streams has been interpreted to reflect proximity of key overwintering areas in tributaries (Kupferberg 1996a). This is consistent with the recent finding that overwintering occurs within the inflow channel, which presents some risk related to scour

(Van Wagner 1996). Thus, tributary streams, which often have a lesser risk of scour than the mainstem of stream systems, may be significant overwintering locations. Juvenile and adult frogs have been frequently observed basking within a body leap of riffle or pool sites (Storer 1925, Fitch 1936, Stebbins 1951, Zweifel 1955, Kupferberg 1996a), so the latter areas are thought to serve as significant refuges (Hayes and Jennings 1988, Jennings and Hayes 1994). Both the precise function of refuges and relative importance of predators that take foothill yellow-legged frog life stages is limited. Available predator information largely addresses garter snakes. The Oregon garter snake *(Thamnophis atratus = hydrophila)*, especially juveniles, are important predators of larvae and recent metamorphs (Lind 1990; Lind and Welsh 1994; Kupferberg 1994, 1996a), whereas common garter snakes (*T. sirtalis*) may be significant predators of postmetamorphs (Fitch 1941, Zweifel 1955, Lind 1990). Scattered records of other predators exist (e.g., Evenden 1948), but the relatively importance of these predators is unknown.

Reports of the disappearance of the foothill yellow-legged frog across significant regions in California (Sweet 1983, Jennings and Hayes 1994) led to speculation that such patterns might exist in Oregon. Several field workers had suggested that disappearances of yellow-legged frogs had occurred locally in southwestern Oregon (Hayes 1995; D. Holland, S. Cross, pers. comm.). Moreover, recent suggestions that substantial habitat change linked to hydrological modifications in northwestern California may have adversely affected this species (Kupferberg 1996b, Lind et al. 1996) raised the possibility that parallel alterations throughout the historic range of the foothill yellow-legged frog in Oregon might have similar consequences. On the basis of this information, the US Fish and Wildlife Service (USFWS) determined that enough evidence existed to justify assessing the status of the foothill yellow-legged frog in Oregon.

For these reasons, we developed a study to assess the status of the foothill yellow-legged frog in Oregon over two years (1997-8). This report presents the data collected during this assessment. Although the USFWS was the lead sponsor, the Oregon Department of Fish and Wildlife (ODFW), the Army Corps of Engineers (ACOE), and the United State Geological Survey (USGS) contributed to the study in important ways. This study was designed to addresses the balance of historical localities that could be surveyed for this species in the state. In the event that the foothill yellow-legged frog was not found over a significant portion of its Oregon range, this study was designed to reveal the potential causes of disappearances. Besides basic findings, this study details an interpretation of patterns and outlines recommendations for future directions and research.

Methods

Determination of historical localities: Historical localities were gathered from museum collections and other verifiable sources. We verified the identities of specimens from museum collections and photographs by examination. An extensive search of sources resulted in a pool of roughly 100 localities for the foothill yellow-legged frog in Oregon. Duplicate descriptions and locations too imprecise to define reduced the list to 90 target localities that could be surveyed. During 1997, one crew surveyed 49 localities from 17 June to 23 September. Two crews surveyed the remaining 41 localities in 1998 and conducted 58 revisits from 2 June to 5 October. A few localities were reconnoitered during winter and early spring 1997 to identify potential logistic problems that might arise during the field season. In addition, at least three spot checks were performed in 1998 at all localities where foothill yellow-legged frogs were not detected (n = 51) on previous surveys. Localities were plotted to the nearest 0.16 km (0.10 mi.) on 7.5' USGS topographic maps. A few descriptions lacked the detail necessary to locate the site to within 0.16 km (0.1 mi). In these cases, the site was located as precisely as description allowed. Historical localities visited are listed in Table 1. In addition to descriptive locality information, latitude and longitude in decimal degrees (DD), elevation in feet (ft) and meters (m), and survey distance in miles (mi) and kilometers (km) are provided.

Survey methods: Known historical localities defined the midpoint of a two-hour time-constrained survey using a two-person crew along a stream reach. Before sampling, a determination was made as to whether a site's channel could be crossed by wading. If less than 50% of the channel length could be crossed by wading, both crew members surveyed the same side of the channel. If at least 50% of the stream could be crossed by wading, each crew member surveyed a different side of the channel. To minimize disturbance to the unsurveyed portion of the reach, surveys were typically conducted in the upstream direction. In four instances, surveys were initiated in a downstream direction to facilitate access or because the reach was surveyed by canoe. If foothill yellow-legged frogs were found, effort was made to obtain a sample of 10 frogs > 40 mm snout-urostyle length (SUL) for meristic data and sexing. If more than 10 frogs > 40 mm SUL were found, only the first 10 that could be captured were measured; remaining individuals were recorded and their size and sex (where determinable) were estimated or noted. For frogs ≤ 40 millimeters SUL (juveniles as assessed in this study) and not manifesting visible sexual characteristics, one individual per transect up to 10 individuals was captured for meristic data and released. Remaining individuals ≤ 40 millimeters were simply tallied. Yellow-legged frog life stages were scored as larvae (= tadpoles), juveniles[2], or adults for all individuals found. Numbers of larvae, where found, were estimated. Water and air temperature, shade, bank slope, channel unit, gradient, embeddedness, flow velocity, and wetted width were all recorded at the point the frog was first observed. Substrate measurements were recorded at three points in a line perpendicular to the wetted edge from where the frog was first seen. The first point was on the wetted edge; the second was one meter towards the mid-channel from the wetted edge; and the last was one meter on shore above the wetted edge.

One water chemistry sample, comprising dissolved oxygen (DO), pH, and nutrient data, was collected at the starting point of each site during 1997. Weather conditions and air and water temperatures were also recorded at this time. In 1998, weather-temperature and DO data were obtained, but nutrient and pH testing were eliminated because the resolution of 1997 data could not discriminate patterns. Physical habitat data were collected independently of the habitat data collected on captured frogs at 20 points along the reach. The first habitat survey point on the reach was selected from a random number table between 1 and 120. The value chosen represented the survey time in seconds before the first physical habitat data were collected. Subsequently, physical habitat data were collected every six minutes thereafter until completion of the reach. Physical variables measured comprised: channel morphology, substrate grain size, shade, bank slope, water depth (at one meter from shore), wetted width, and gradient. A human disturbance variable was scored into one of eight categories: logging, grazing, roads, recreation, residences, trash, no observed disturbance, and a miscellaneous category that represented anything not included in this list. This variable was recorded for each of the 20 points along the reach. Surveyors scored the human disturbance variable visually in an area approximately 50 meters by 50 meters centered on each point. Stream discharge, measured in cubic feet per second (cfs), was collected using a March-McBirney™ flow meter once per reach. A photograph was taken at the tenth habitat point of each reach to photodocument conditions. Observations and any other miscellaneous features deemed potentially important to interpreting the patterns of foothill yellow-legged frog distribution were recorded in the field notes. An attempt was made to assess coarse changes in geomorphology, human disturbance, and vegetation for selected sites through a comparison of historical and current aerial photographs. Aerial photointerpretation also aided in determining the degree of site isolation resulting from hydrological modifications.

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[2] Metamorphosing individuals with four legs, but which still had a tail were scored as juveniles. The egg stage was not scored because surveys were conducted after oviposited masses had hatched.

To optimize detection of foothill yellow-legged frogs at historical localities and to assess error associated with detection, historical localities at which no frogs were found during the first site survey were revisited. In a few cases, more than one revisit was conducted. Biotic data, air and water temperature data, and field notes were recorded on revisits. Remaining physical variables collected during the initial surveys were not remeasured. In addition, a minimum of three 15-minute spot checks in the proximity of historical localities were conducted to provide additional perspective on detection error and to improve resolution of geographic and regional patterns. Where possible, these supplemental spot checks were performed in the same drainage as the historical site. These checks were done in areas deemed good potential habitat for *Rana boylii*. Spot check locations often included the mouths of tributaries that enter larger-order drainages; coarse-substrate bars; areas with a complex channel morphology; and open, south-facing reaches because these locations possessed characteristics that were deemed good potential habitat.

Data treatment and analyses: Data were summarized and analyzed according to standard statistical procedures (Zar 1996). Variables were plotted using histograms to visualize distributions and then evaluated for normality using Anderson-Darling tests (Ryan and Joiner 1976). Some variables were adjusted for differences in sample sizes when performing univariate and multivariate analyses. For analytical purposes, localities were classified as primary or secondary watersheds. Primary watersheds were all drainages with outlets reaching the coast except in the case of the Willamette River. Secondary drainages were tributaries of the mainstem of primary drainages. For the purposes of discussion and some comparisons, watersheds were partitioned into size categories based on drainage area in square miles (mi^2). Categories included very small ($< 50\ mi^2$), small (50 to $< 500\ mi^2$), moderate-sized (500 to $< 4000\ mi^2$), and large ($\geq 4000\ mi^2$) drainages.

Comparisons were made between localities with frogs (LWF) and localities lacking frogs (LLF) for channel morphology, human disturbance, selected continuous variables, and substrate using Mann-Whitney tests. Principal Component Analysis (PCA) was used for similar exploration of the aforementioned variable categories. Two alternative analyses of habitat variables at LWF versus LLF were performed with PCA. The first compared physical habitat data of each type of locality, whereas the second compared physical habitat data from LLF with frog-specific data from LWF. Channel morphology and substrate variables were also grouped for some analyses. Comparison was also made between localities judged influenced or uninfluenced by impoundments using a Chi-Square test. For this analysis, a large impoundment, one with a maximum pool surface area of at least 50 ha, had to be present upstream to consider the locality impoundment-influenced. Additional comparisons were made using Chi-square analysis for sites recorded as having or lacking bullfrogs, or native versus exotic fishes. A Kruskal-Wallis non-parametric ANOVA was used to compare the coded human distribution variable among watershed categories. A Spearman rank correlation co-efficient (ρ) was used to compare numbers of historical localities and watershed areas. For the latter analysis, we included only those watersheds that had the opportunity to be entirely encompassed within the Oregon range of the foothill yellow-legged frog. As a consequence, the Klamath, Smith, and Willamette watersheds were excluded from this analysis either because the geographic range was only marginally included with the watershed, the watershed was partly outside Oregon, or both.

Unless stated otherwise, rejection criteria for making Type I (α) and Type II (β) errors were set at 0.05 and 0.20, respectively. When more than one test used the same data, α

was adjusted conservatively for the number of tests (n) using Sidak's multiplicative inequality $\alpha' = 1-(1-\alpha)^{1/n}$.

Results

Statewide - Over two field seasons in 1997-8, more than 3,000 person hours were spent surveying over 300 river miles across 90 Oregon localities (Table 1). Dispersion of sites differed substantially across watersheds. Localities were dispersed more thinly across the northern part of this range and generally increased in density towards the south and west (Figure 1). This asymmetry was superimposed on a patchy distribution of sites linked in part to hydrographic basin (= primary watershed) size (Figure 2). Number of historical localities was strongly correlated with watershed area (Spearman rank $\rho = 0.703$, $n = 12$, $0.02 < p < 0.01$). The Rogue watershed had by far the greatest number of historical sites with over 40% ($n = 39$) of historical localities surveyed. In contrast, the Williamette had about 15% ($n = 14$) of historical sites, and the Umpqua had ca. 13% ($n = 12$). Remaining drainages combined for the 26.6% ($n = 24$) of remaining localities. Clusters of localities, often near county and state parks, were found along major drainages.

Foothill yellow-legged frogs were detected at 43.3% of target localities (39 of 90). Of localities with yellow-legged frogs, few ($n = 7$) had many individuals ($n \geq 10$; Figure 3), and nearly half of the localities had at least three life stages ($n = 19$). At just over half the localities (19 of 39) where frogs were detected, five or fewer individuals were found. In addition, we found the postmetamorphic stages of foothill yellow-legged frogs during resurveys of four localities at which no frogs had been found during the original surveys. The number of frogs found at these four sites was four or fewer. During spot checks near historical localities where no frogs were found ($n \geq 160$), we found foothill yellow-legged frogs at three additional sites.

Habitat variables - Univariate analyses showed that coarse substrates (> 2 mm) were significantly more frequent at LWF than at LLF (Table 2, Appendix I). All observations of foothill yellow-legged life stages found them frequently using fine gravel, coarse gravel, or cobbles. Tadpoles were typically observed swimming in interstitial spaces among gravels and cobbles, whereas juveniles and adults were often found on and among coarse

Table 1. Location, timing, survey distance and results for localities.

Major Drainage	Site Number	Location	Latitude (DD)	Longitude (DD)	Elevation (ft)	Elevation (m)	Initial Survey Date	Survey Distance (mi)	Survey Distance (km)	Yellow-legged frogs recorded (+)
Brush Creek	44	Humbug Mountain State Park	42.6883775	124.431960	60	18	06/20/97	1.4	2.2	
Chetco River	47	Alfred Loeb State Park on the Chetco River River	42.1073516	124.189241	40	12	07/06/98	1.9	3.1	+
Chetco River	56	Chetco River River: Rd. 2.9 miles E of Hwy 101	42.0639202	124.228577	10	3	08/11/97	2.2	3.5	+
Chetco River	46	Joe Hall Creek: 2 miles E of Brookings	42.0880404	124.257740	80	24	06/17/97	1.6	2.6	
Chetco River	58	Little Redwood Forest Camp	42.1525052	124.148850	70	21	08/13/98	2.0	3.2	+
Chetco River	59	Long Ridge Forest Camp: 0.25 miles E of Packers Cabin	42.2380091	124.078238	1360	415	06/23/97	1.0	1.6	+
Coos River	36	South Fork Coos River: Marshfield	43.3741680	124.073436	40	12	08/10/98	2.9	4.7	
Coquille River	33	17.0 miles south of Powers	42.7288558	124.044829	920	280	08/04/97	2.1	3.4	+
Coquille River	34	2 miles NE of Dora	43.1617547	123.922522	170	52	08/03/97	1.8	2.9	
Coquille River	35	South Fork Coquille River River: Myrtle Point	43.0650465	124.148223	40	12	08/19/98	2.0	3.2	
Elk River	42	Elk River: 10 miles E-SE of Port Orford	42.7128051	124.310532	440	134	08/20/98	2.4	3.9	+
Elk River	60	Lost Creek: tributary of Elk River near Panther Creek	42.7110780	124.266604	1200	366	08/22/98	1.4	2.2	+
Elk River	41	Panther Creek at Elk River	42.7144048	124.282615	580	177	06/19/97	1.2	1.9	+
Hooskanaden	55	Hooskanaden Creek: 14 miles south of Rogue River RiverRiver bridge	42.2139943	124.366583	150	46	07/14/98	1.8	2.9	
Klamath River	95	Cottonwood Creek: 3 miles off Colestin Rd.	42.0168163	122.644594	2940	896	09/08/97	2.2	3.5	
Klamath River	104	Klamath River River: 13 miles above the CA state line	42.1108297	122.055707	3610	1100	07/24/97	1.8	2.9	
Klamath River	99	Shoat Springs: 6.8 miles along Copco Rd.	42.0344313	122.339236	3270	997	07/22/97	2.2	3.5	
Myers Creek	52	Myers Creek: 12 miles S of Gold Beach	42.3061251	124.395585	120	37	07/08/98	1.5	2.4	
Pistol River	53	Pistol River near mouth	42.2678554	124.395537	10	3	08/23/98	2.4	3.9	+
Rogue River	48	Jerry Flat Road: 0.25 miles E of Saunders Creek	42.4588176	124.372376	20	6	07/07/98	2.2	3.5	+
Rogue River	84	1.4 miles S of Copper 250 m E of Elliot Creek	42.0204152	123.131811	2440	744	08/11/98	2.0	3.2	+
Rogue River	86	Beaver Creek: 0.25 miles upstream from Applegate River	42.1153856	123.067850	1770	539	07/16/97	1.9	3.1	
Rogue River	38	10 miles E of Gold Beach on Rogue River RiverRiver	42.5014032	124.282404	40	12	07/12/98	2.0	3.2	+
Rogue River	91	11.5 miles above mouth of Little Applegate River	42.1498925	122.875783	2510	765	07/31/98	1.7	2.7	
Rogue River	64	2 miles E of Cave Junction along a small stream	42.1477622	123.609104	1380	421	07/05/97	1.5	2.4	+
Rogue River	50	3.4 miles up North Bank Rogue River RiverRiver Road to Libby Creek	42.4884868	124.336733	120	37	07/04/98	1.2	1.9	
Rogue River	65	Mendenhall Creek: 3.5 miles S of Cave Junction	42.1218141	123.670955	1340	408	07/16/98	2.0	3.2	+
Rogue River	102	4 miles from West Evans Creek Rd. at Source of Graves Creek	42.7436875	123.143283	3240	988	08/01/97	1.9	3.1	
Rogue River	54	5 miles east of Gold Beach on south side of Rogue River RiverRiver	42.4655966	124.348811	60	18	06/21/97	1.8	2.9	+
Rogue River	67	9 mile NW of Grants Pass- half way to Galice	42.5164278	123.455886	850	259	07/10/97	2.4	3.9	
Rogue River	93	Antelope Creek: Eagle Point	42.4581207	122.819429	1285	392	07/18/97	2.0	3.2	
Rogue River	85	Applegate River: 3 miles above the mouth	42.3958832	123.454259	900	274	07/22/98	1.9	3.1	
Rogue River	94	Bear Creek: Ashland	42.1987918	122.687279	2240	683	07/23/97	2.0	3.2	
Rogue River	78	Bunker Creek: N side of Rogue River RiverRiver	42.6611349	123.719744	850	259	08/27/97	1.5	2.4	+
Rogue River	83	Carberry Creek: 0.5 miles NW of Applegate Reservoir	42.0338886	123.173245	2050	625	07/15/97	2.0	3.2	+
Rogue River	71	East Fork Illinois River: 3 miles W of Holland	42.1314880	123.613881	1340	408	07/06/97	1.8	2.9	+
Rogue River	81	Elk Creek: 3.5 miles E of Trail	42.6713447	122.743582	1480	451	08/04/98	2.0	3.2	
Rogue River	82	Evans Creek: 17.7 miles from the mouth at Rogue River RiverRiver	42.5937830	122.962307	1670	509	06/05/98	1.5	2.4	+
Rogue River	43	Flora Dell Creek	42.6673680	124.063132	960	293	08/29/97	1.6	2.6	
Rogue River	72	Grayback Creek: 1 mile E of junction with Sucker Creek	42.1473222	123.431680	2000	610	06/26/97	1.7	2.7	
Rogue River	75	Junction of Hwy 99 and Hwy 46 on the East Fork Illinois River	42.1566411	123.647586	1300	396	07/07/97	2.1	3.4	+
Rogue River	97	Hamilton Creek: Junction of Hwy 66 and Faith Lane	42.1838347	122.675042	2040	622	08/06/98	2.3	3.7	
Rogue River	87	Kesler Creek on Applegate River	42.2293566	123.135221	1760	536	07/25/98	1.8	2.9	
Rogue River	73	Little Grayback Creek: 10.8 miles E of Cave Junction	42.1684868	123.469962	1960	597	07/03/97	1.5	2.4	+

Table 1. Location, timing, survey distance and results for localities.

Major Drainage		Location	Latitude (DD)	Longitude (DD)	Elevation (ft)	Elevation (m)	Initial Survey Date	Survey Distance (mi)	Survey Distance (km)	Yellow-legged frogs recorded (+)
Rogue River	88	McKee Bridge: 8.9 miles S of Ruch	42.1255172	123.074485	1610	491	07/17/97	2.0	3.2	
Rogue River	98	NE Ashland: 0.5 miles NW of Scenic Hills Cemetery	42.2064428	122.676885	1930	588	08/08/98	1.7	2.7	
Rogue River	74	Near Sucker Creek:100 yards from Grayback Camp	42.1424894	123.461795	1820	555	07/04/97	2.1	3.4	
Rogue River	89	Poorman's Creek: 0.5 mile above Forest Creek	42.2724359	123.023136	1800	549	07/30/98	1.7	2.7	
Rogue River	76	Rainie Falls: north side of Rogue River RiverRiver	42.6497243	123.614850	590	180	08/26/97	2.0	3.2	
Rogue River	40	Ravine about 1.8 miles west of Lobster Creek	42.4794348	124.303448	80	24	07/13/98	1.4	2.2	+.
Rogue River	96	Roxy Ann Mountain in South Drainage	42.3421127	122.781199	2200	671	07/29/98	1.7	2.7	
Rogue River	66	Shoodle Creek	42.3094811	123.720984	1280	390	06/25/97	1.8	2.9	+
Rogue River	70	Slate Creek: 11 miles S of Grants Pass	42.3080848	123.488776	965	294	07/09/97	1.8	2.9	+
Rogue River	90	Squaw Creek Rd. 0.5 miles from upper Applegate Rd.	42.0341635	123.098273	2150	655	08/09/98	2.3	3.7	
Rogue River	68	Store Gulch: W of Selma	42.3020257	123.758091	1560	475	06/24/97	1.4	2.2	+
Rogue River	69	Sucker Creek: 5.6 miles W of Grayback Forest Camp	42.1514884	123.534882	1540	469	07/23/98	2.4	3.9	+
Rogue River	79	Trail Creek: 0.5 miles N of Junction W Fork Trail	42.6806349	122.848250	1740	530	06/04/98	2.1	3.4	+
Rogue River	80	Trail Creek: 6 miles above the mouth	42.7170454	122.835497	1820	555	07/25/97	2.0	3.2	+
Smith River	77	Diamond Creek: 9 miles W and 4 miles S. of O'brien	42.0861083	123.888139	1800	549	07/24/98	1.8	2.9	+
Tuttle Creek	45	Harbor Oregon	42.0446783	124.250776	100	30	06/17/97	1.2	1.9	
Umpqua River	17	27.5 miles E of Gardiner	43.7994274	123.809581	140	43	08/3/97	2.0	3.2	
Umpqua River	32	Coffee Creek	42.9443229	122.987086	1040	317	06/02/98	2.0	3.2	+
Umpqua River	31	Cow Creek: 12 miles from Riddle	42.8788624	123.563223	920	280	06/03/98	1.4	2.2	+
Umpqua River	30	Cow Creek at Hwy99	42.9425046	123.345198	650	198	07/29/97	2.1	3.4	
Umpqua River	20	Drain: Elk Creek	43.6683729	123.316116	300	91	08/05/97	1.8	2.9	
Umpqua River	19	Elk Creek: 2 miles E of Elkton	43.6427891	123.538530	120	37	06/21/98	1.8	2.9	
Umpqua River	18	Johnson Creek: 30 miles E of Gardiner	43.8154877	123.794870	280	85	06/20/98	2.0	3.2	
Umpqua River	26	Little River: 1 mile E of Glide	43.2432751	122.927012	1120	341	08/05/98	2.0	3.2	+
Umpqua River	25	Myrtle Creek	43.0203680	123.279380	590	180	07/30/97	2.3	3.7	
Umpqua River	22	North Fork Deer Creek: 8 miles E of Roseburg	43.2071383	123.165676	840	256	06/07/98	2.1	3.4	
Umpqua River	24	North Umpqua River: E of Winchester	43.3008884	123.308892	480	146	06/06/98	2.1	3.4	+
Umpqua River	27	Rock Creek: off of North Umpqua River	43.3996253	122.924849	1115	340	09/02/97	2.0	3.2	+
Willamette River	9	5 miles E of Sweet Home	44.4095425	122.683662	590	180	08/19/97	1.7	2.7	
Willamette River	2	6.3 miles E of Lebanon	44.4091643	122.774479	410	125	08/21/97	1.7	2.7	
Willamette River	5	6.3 miles E of Foster	44.4098865	122.565432	630	192	08/22/97	1.9	3.1	+
Willamette River	16	Alder Creek: E of Lowell	43.9147599	122.668889	1360	415	08/07/97	1.4	2.2	
Willamette River	15	Bigfall Creek: E of Lowell	43.9653514	122.619363	895	273	08/08/97	2.0	3.2	
Willamette River	6	Cascadia	44.3882472	122.479873	985	300	08/11/97	1.8	2.9	
Willamette River	13	Dell Creek: Shady Dell Campground	43.7873116	122.547429	1180	360	06/14/98	1.5	2.4	
Willamette River	14	Laying Creek: off Row River Disston	43.7043782	122.763347	1165	355	08/23/97	1.8	2.9	
Willamette River	1	Mehama	44.7888484	122.616720	590	180	08/13/97	2.0	3.2	
Willamette River	7	Moose Creek	44.4107141	122.431768	985	300	08/08/97	1.8	2.9	
Willamette River	11	Mouth of the McKenzie River	44.1238326	123.103799	370	113	06/12/98	2.0	3.2	
Willamette River	12	Rolling Riffle Creek	43.8714834	122.712382	1040	317	06/13/98	1.8	2.9	
Willamette River	28	Row River: at Disston	43.7018951	122.709511	1095	334	08/06/97	1.9	3.1	
Willamette River	10	Willamette River River: near Corvallis	44.5739938	123.251233	210	64	08/27/98	2.0	3.2	
Winchuck River	105	1.6 miles N of Winchuck River Campground	42.0411699	124.103118	200	61	08/12/98	1.9	3.1	+
Winchuck River	51	Winchuck River River	42.0114902	124.130868	120	37	07/05/98	1.8	2.9	+
Winchuck River	61	Winchuck River River: 4.5 miles from Hwy 101	42.0324167	124.160285	40	12	07/03/98	1.7	2.7	+
Winchuck River	62	Winchuck River River Rd; 0.2 miles W of Winchuck River River	42.0210363	124.106100	130	40	06/18/97	1.8	2.9	+

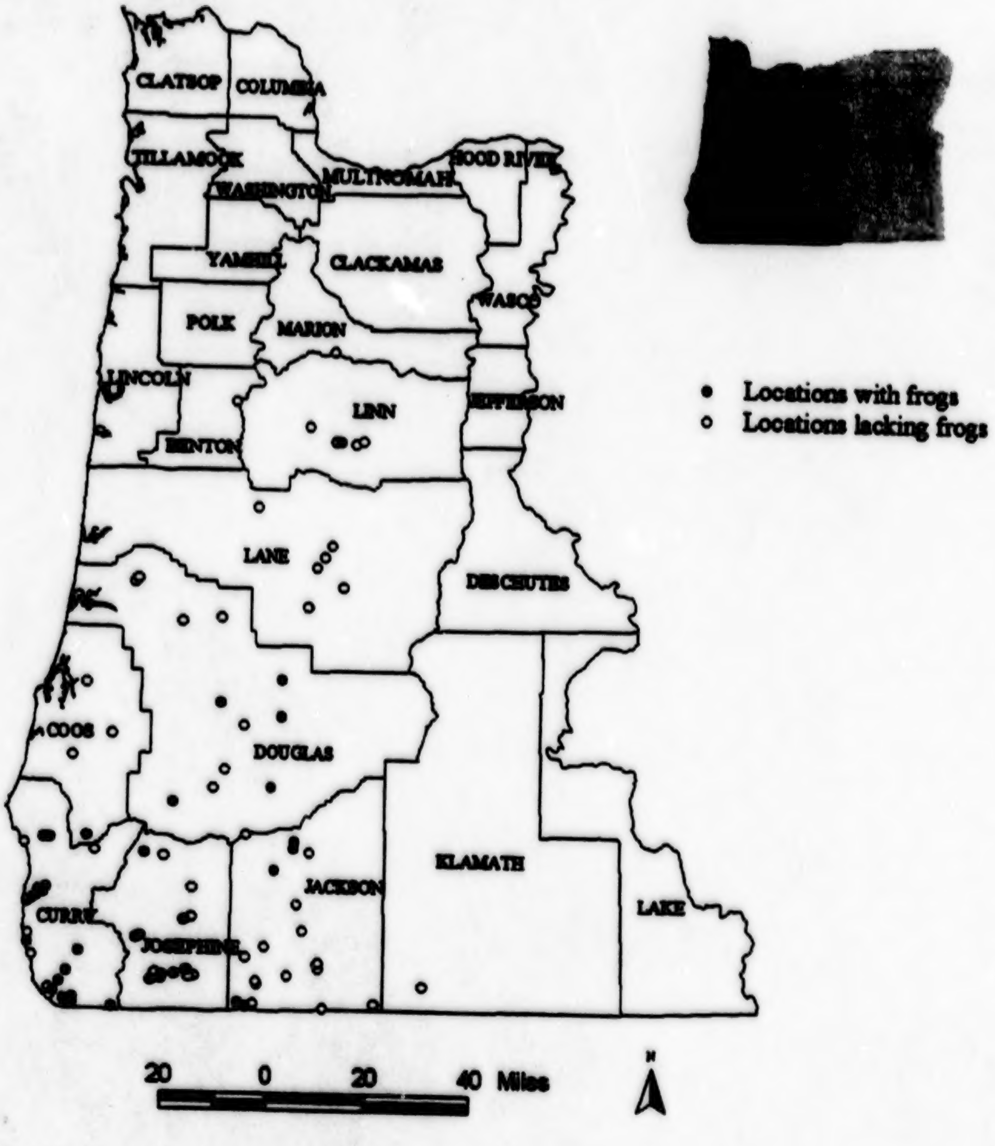

Figure 1. Foothill yellow-legged frog historical localities in Oregon.

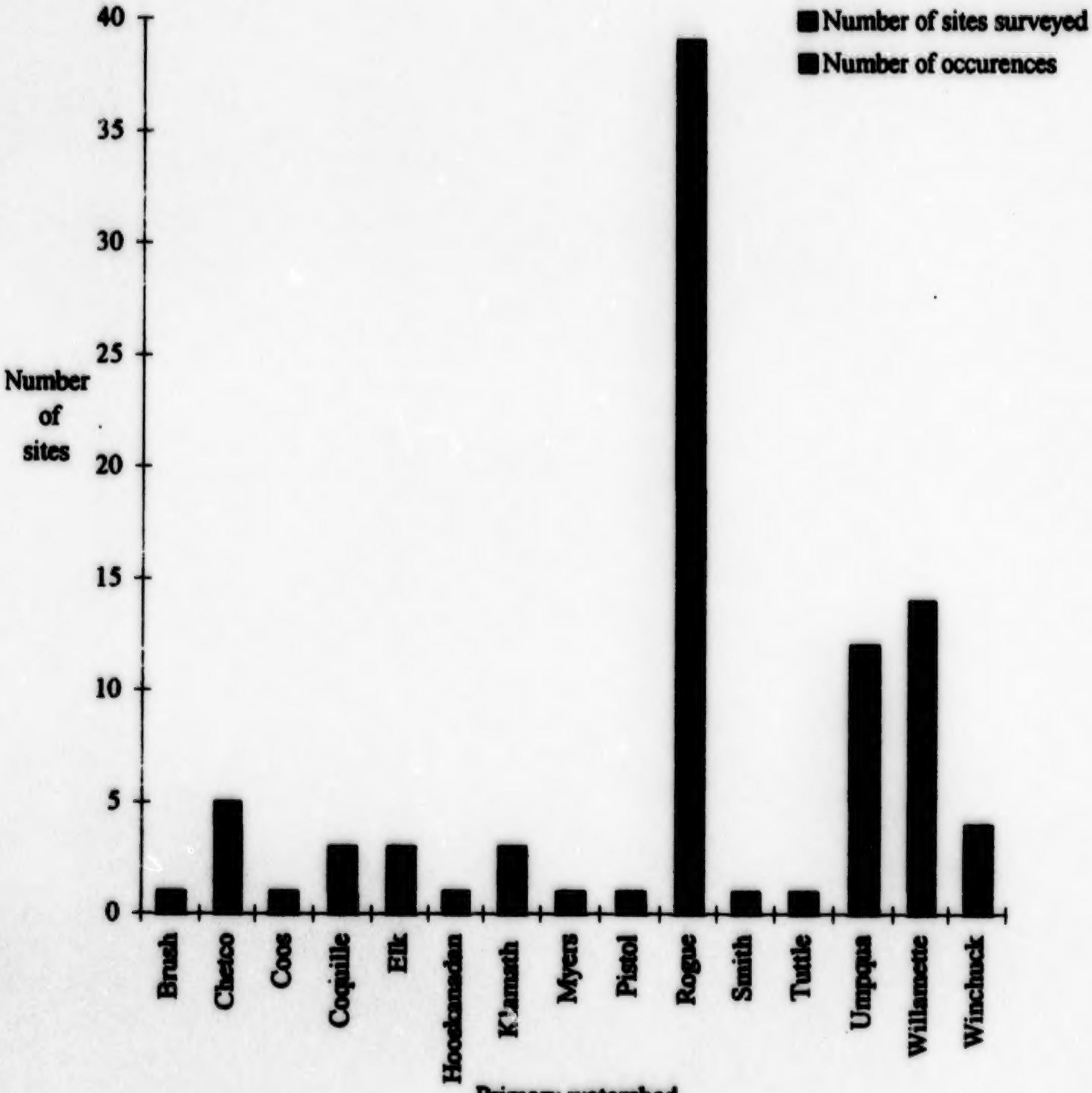

Figure 2. Foothill yellow-legged frog occurrence by primary watershed

(Sites with 100% occurrence level conceals the red indicating the number of sites surveyed.)

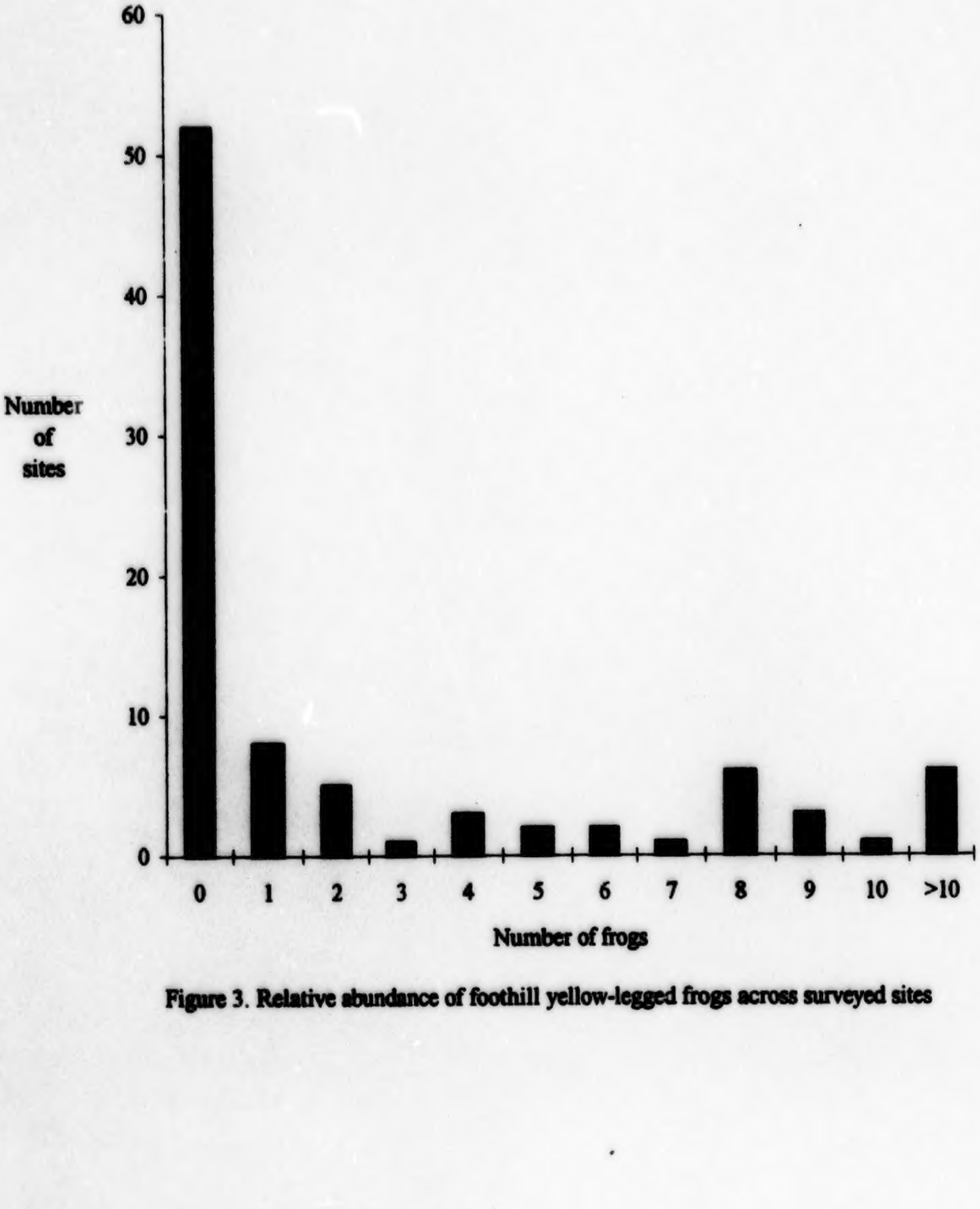

Figure 3. Relative abundance of foothill yellow-legged frogs across surveyed sites

Table 2. Substrate comparison across sites

Substrate category[1]	Frogs present[2] (N=39)	Frogs not present (N=51)	U[3]	Probability[4] (p)
SI	4.0	8.0	1501	**0.0251**
SA	13.0	18.0	1538	0.0545
FG	8.0	6.0	1895	0.3251
CG	24.0	19.0	1970	0.1122
CB	10.0	12.0	1709	0.599
BL	6.0	9.0	1712	0.6108
BD	18.0	10.0	1937	0.1857
COARSE	83.0	72.0	2035	**0.0343**
FINE	19.0	36.0	1496	**0.0233**
EMBEDDED	35.0	50.0	2615	**0.0236**

embolded values significant at 0.05

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[1] SI= Silt; SA= Sand; FG= Fine gravel; CG= Coarse gravel; CB= Cobble; BL= Boulder, BD= Bedrock; COURSE= FG+CG+CB+BL+BD; FINE= SI+SA; EMBEDDED= >50% FINES

[2] Values represent medians

[3] U is the test statistic that represents the sum of the ranks for sample 1.

[4] Adjusted for ties

substrates (A. Borisenko, pers. observ.). Conversely, fine substrates (< 2 mm), silt alone, or coarse substrates embedded in silt or sand were significantly less frequent at LWF than at LLF. Principle Component Analysis using physical habitat variables did not distinguish a pattern between LWF and LLF. In contrast, PCA analysis using frog-specific data strongly distinguished the LWF cluster from the LLF cluster. The latter showed some similarity to univariate analyses. Locations with frogs clustered with increasing fractions of coarse substrates, higher water temperatures, and slower water velocities (Figure 4).

Univariate analyses detected no differences in channel morphology between LWF and LLF (Table 3; Appendix II). Similarly, no differences were found among continuous physical variables between LWF and LLF (Table 4).

Human Disturbance - Detectable differences in disturbance regimes across all localities using categorical human disturbance codes were slight (Table 5; Appendix III). Grazing (GR) and No observable disturbance (NO) were the only categories that were significantly different between LWF and LLF. Field observations indicated a high degree of variability in types of disturbance across localities. Moreover, differences were found in the human disturbance variables when comparing drainage size categories, but they were statistically not significant (Kruskal Wallis adjusted for ties: $H = 4.68$, $df = 3$, $p = 0.197$).

Besides the aforementioned, patterns linked to impoundments were a prominent feature of foothill yellow-legged frog distribution. Isolation or inundation related to impoundments were prominent among disturbance features recorded. Sixteen (17.7%) of 90 sites were either upstream isolates ($n = 14$) and/or inundated ($n = 6$) by large (> 50 ha) reservoirs. An additional 15 (16.6%) historical localities were downstream from a large reservoirs. Comparison of LWF with LLF revealed a significant asymmetry with respect to large reservoirs. Only two LWF were located below large reservoirs compared to 13 LLF, whereas 37 LWF and 38 LLF were above large reservoirs or located on systems that lacked large reservoirs (Chi-Square: $\chi = 6.60$, $df = 1$, $p = 0.01$).

Foothill yellow-legged frog data - We observed 2,096 metamorphs and postmetamorphic foothill yellow-legged frogs (MPFs) over two seasons. We measured and collected habitat data for 164 MPFs and estimated SUL and collected habitat data for another 52 MPFs.

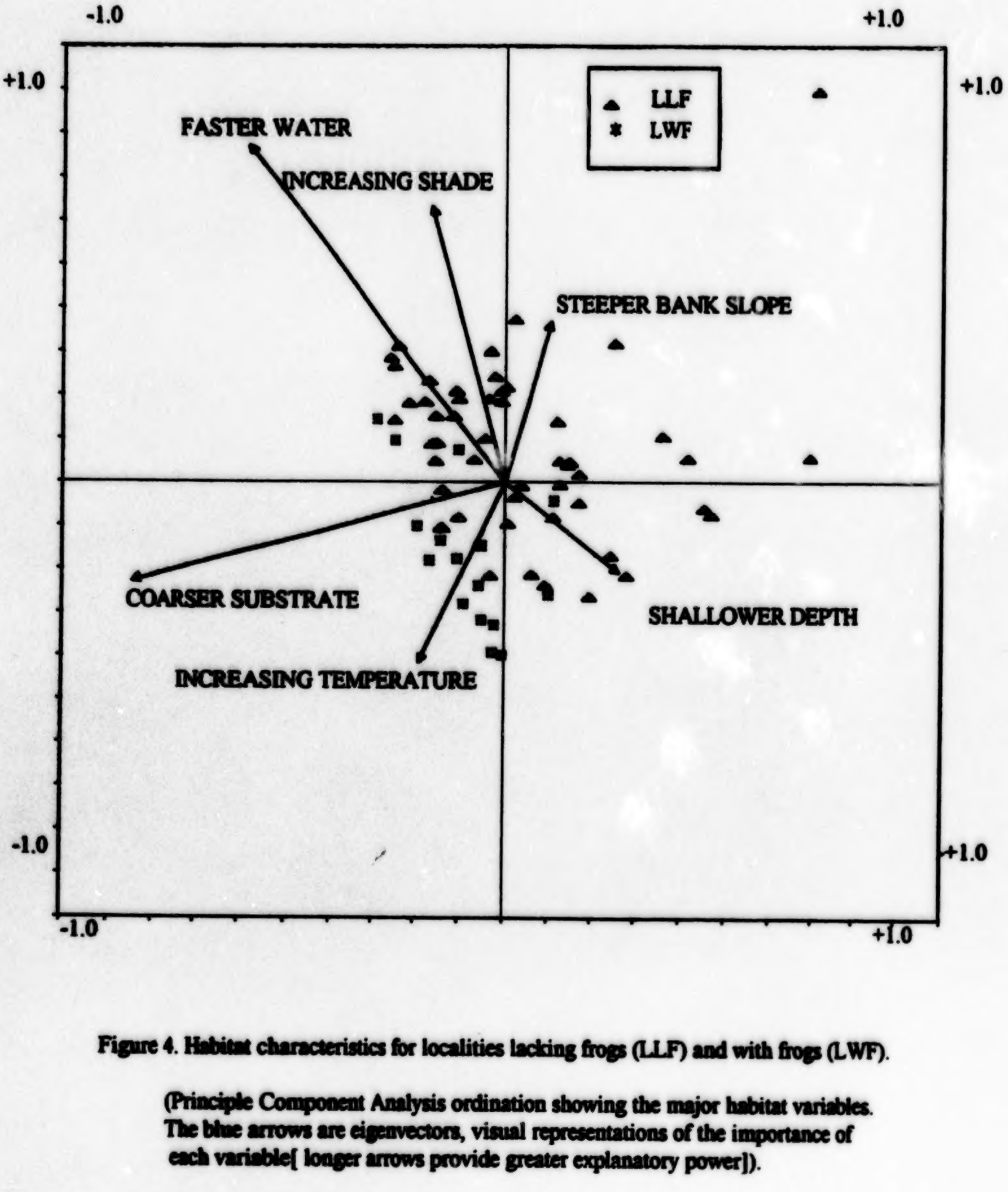

Figure 4. Habitat characteristics for localities lacking frogs (LLF) and with frogs (LWF).

(Principle Component Analysis ordination showing the major habitat variables. The blue arrows are eigenvectors, visual representations of the importance of each variable[longer arrows provide greater explanatory power]).

Table 3.Comparison of channel morphology across sites

Channel Unit[1]	Frogs present[2] (N=39)	Frogs not present (N=39)	U[3]	Probability[4] (p)
FA	15.0	6.5	21.5	0.5043
CA	10.0	10.0	242.5	0.6713
RA	20.0	20.0	1093.5	0.7516
RI	28.0	37.0	1610.0	0.1809
GL	32.0	26.0	1261.0	0.5262
PT	20.0	15.0	1902.0	0.2998
FAST	55.0	56.0	1673.0	0.4129
SLOW	45.0	44.0	1875.0	0.4152

emboldened values significant at 0.05

[1] FA= Falls; CA= Cascade; RA= Rapid; RI= Riffle; GL= Glide; PT= Pool total; FAST= FA+CA+RA+RI; SLOW= GL+PT

[2] Values represent medians

[3] U is the test statistic that represents the sum of the ranks for sample 1

[4] Adjusted for ties

Table 4. Comparison of continuous variables across sites

Habitat parameters	Frogs present[1] (N=39)	Frogs not present (N=51)	U[2]	Probability[4] (p)
SHADE	60.4	68.8	1564	0.0865
BANK SLOPE	27.6	32.4	1614	0.1926
DEPTH	22.6	19.4	1870	0.4392
WETTED WIDTH	11.0	10.0	1843	0.4668
GRADIENT	0.7	1.2	1580	0.1140

emboldened values significant at 0.05

[1] Values represent medians

[2] U is the test statistic that represnets the sum of the ranks for sample 1

[3] Adjusted for ties

Table 5. Comparison of human disturbance categories across sites

Human Disturbance Factors[1]	Frogs present[2] (N=39)	Frogs not present (N=51)	U[3]	Probability[4] (p)
OT	3.0	6.0	1583	0.1165
LG	24	22	1783	0.9509
GR	0.0	0.0	1555	**0.0331**
TR	11.0	11.0	1711	0.6075
RC	14.0	6.0	1937	0.1833
RD	23.0	25.0	1653	0.3241
RS	0.0	3.0	1665	0.3447
NO	0.0	0.0	1987	**0.0451**

emboldened values significant at 0.05

[1] OT= Other; LG= Logging; GR= Grazing; TR= Trash; RC= Recreation; RS= Residences; RD=Roads; NO= No disturbance observed

[2] Values represent medians

[3] U is the test statistic that represents the sum of the ranks for sample 1.

[4] Adjusted for ties

Over 70% of all MPFs recorded came from a single site, Little Redwood Forest Camp on the Chetco River. Of remaining localities with MPFs, 75% of the individuals came from six localities. Juveniles ($\leq$ 40 mm) were 88.5% of MPFs (Figure 5).[3]

Tadpoles, estimated at just over 5,900 individuals, were observed at slightly over half of the localities where yellow-legged frogs were found (n = 20).

Foothill yellow-legged frogs were usually found among coarse substrates (> 80% of the time) that were not embedded (72%) on shallow sloping banks (13.4° ± 13.7°). Typically, yellow-legged frogs occupied open areas with only partial shade (31% shade ± 34%) in or near water with a low flow velocity (0.04 m/s [0.14 f/s] ± 0.09 m/s [0.28 f/s] at 1 m from shore) that was adjacent to water of intermediate to fast flow velocities (Figure 6).

Other biotic data - Bullfrogs (*Rana catesbeiana*) were found at over one quarter of the historical localities (28% [25 of 90]). Foothill yellow-legged frogs occurred at only four localities at which bullfrogs were also found (Figure 7). In contrast, bullfrogs were found at 21 sites where yellow-legged frogs were not detected, and yellow-legged frogs were found at 35 sites where bullfrogs were not detected. This distributional asymmetry was significant (Chi-Square: $\chi = 6.60$, df = 1, $p = 0.01$).

Fish were not reliably scored across localities because adequate visual observations were intermittent and turbidity was variable. Moreover, positive identification was only irregularly possible because observed fish were rarely captured. Nevertheless, at least 10 fish taxa, six native (a sculpin [*Cottus* sp.], Chinook salmon [*Oncorhynchus tshawytscha*], cutthroat trout [*O. clarki*], Pacific lamprey [*Lampetra tridentata*], Umpqua pike minnow [*Ptychocheilus umpquae*], speckled dace [*Rhinichthys osculus*]) and four exotics (brown bullhead [*Ameiurus nebulosus*], mosquitofish [*Gambusia affinis*], pumpkinseed [*Lepomis gibbosus*], smallmouth bass [*Micropterus dolomieui*]), were positively identified during foothill yellow-legged frog surveys. Moreover, a significant asymmetry was observed in the distribution of exotic fishes across historical foothill yellow-legged frog sites (Figure 8). Exotic fishes were observed at significantly more LLF than LWF (Chi-Square: χ =

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[3] Frogs $\leq$ 40 mm SVL were assumed to be juveniles unless secondary sexual characteristics could be discerned. Males were distinguished from females by enlarged forearms and nuptial pads on digit one.

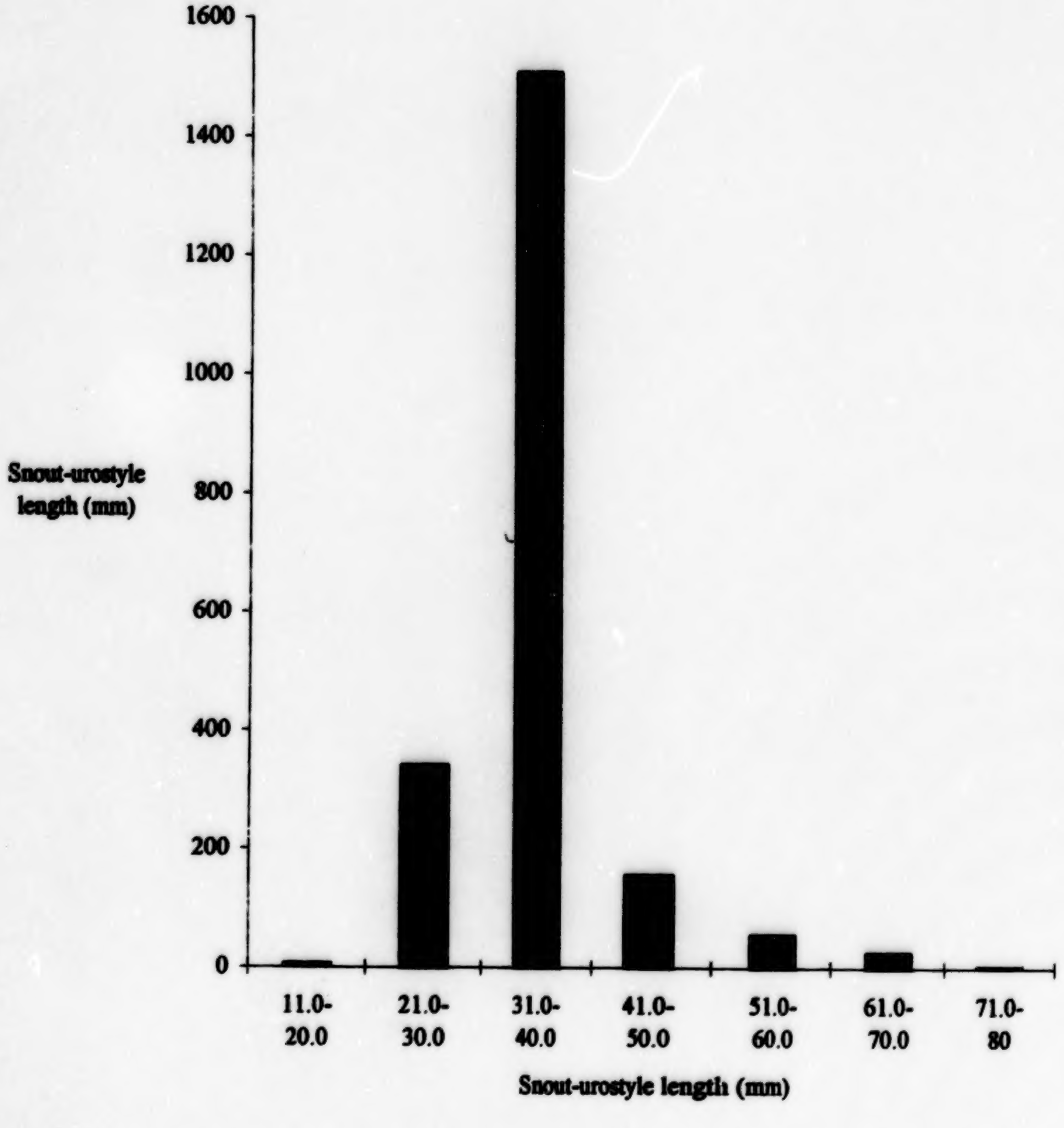

Figure 5. Size distribution of metamorphosing and postmetamorphic foothill yellow-legged frogs

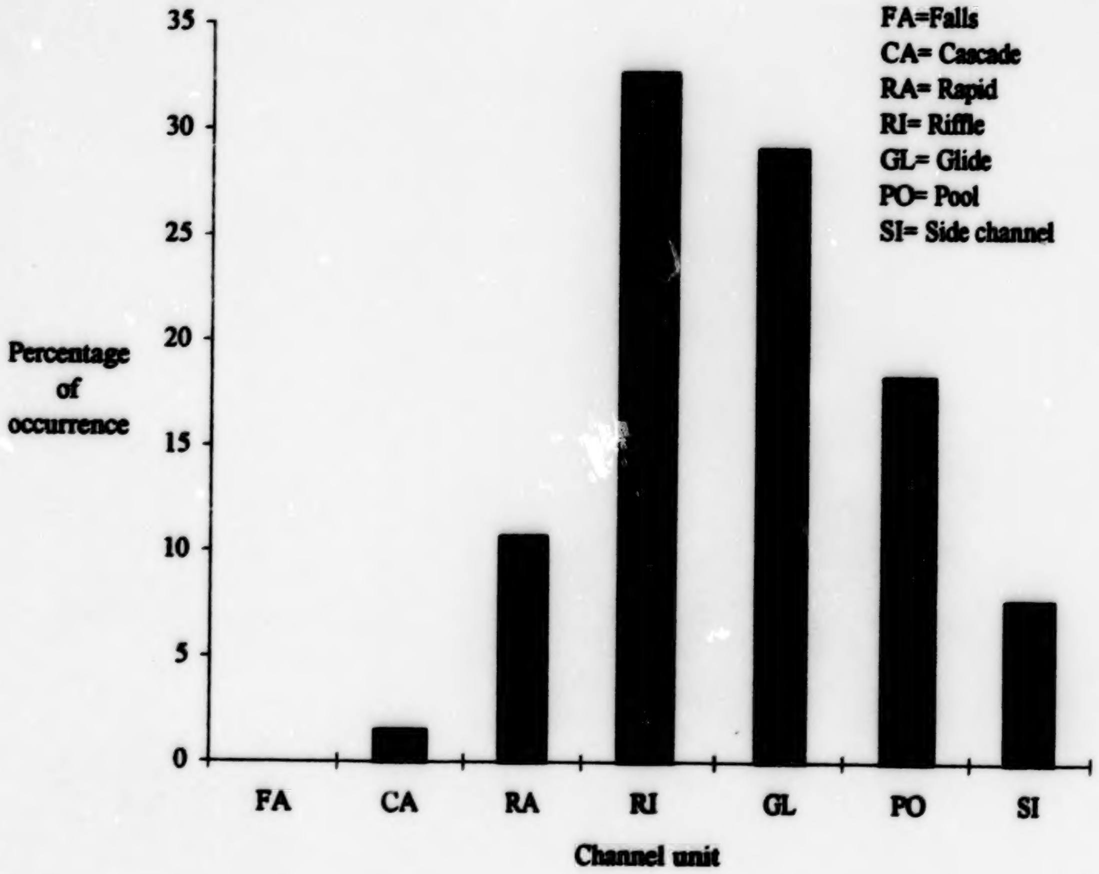

Figure 6. Foothill yellow-legged frog association with channel morphology

(Channel morphology categories are arrayed in order of decreasing flow velocity from left to right)

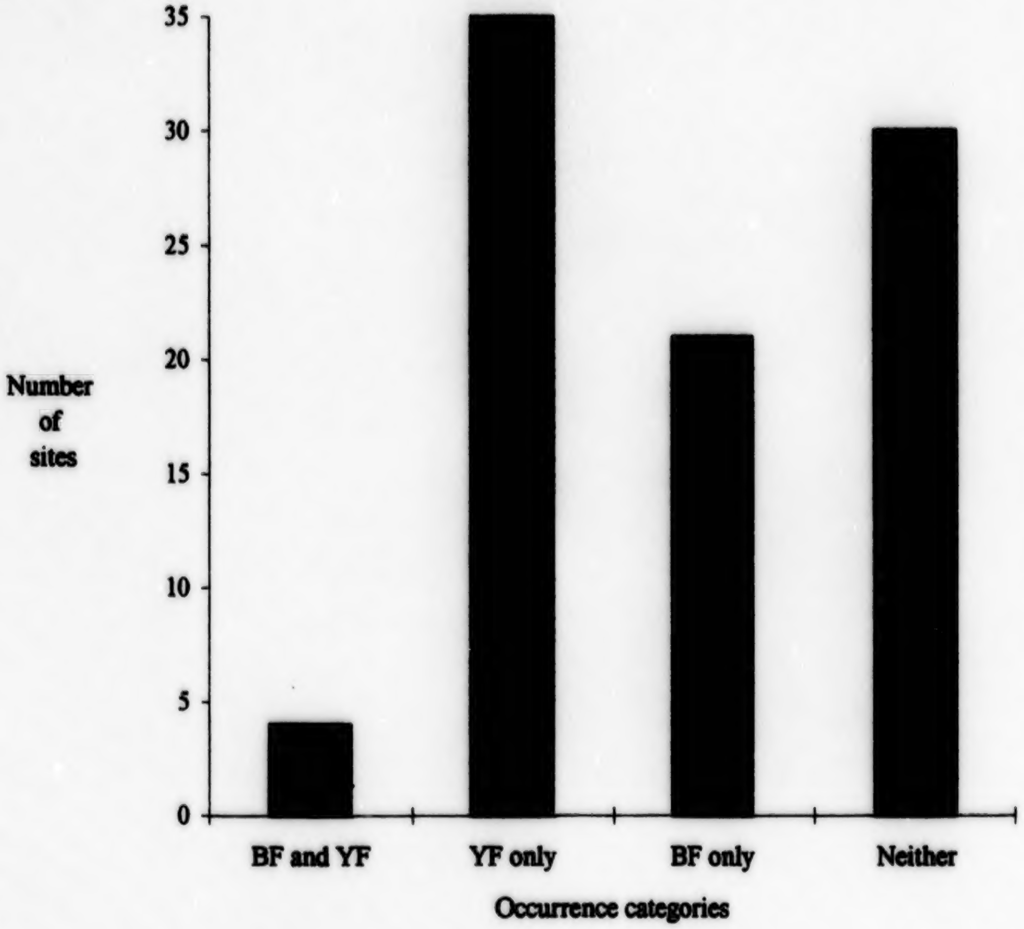

Figure 7. Bullfrog (BF) and Foothill yellow-legged frog (YF) at historical YF sites

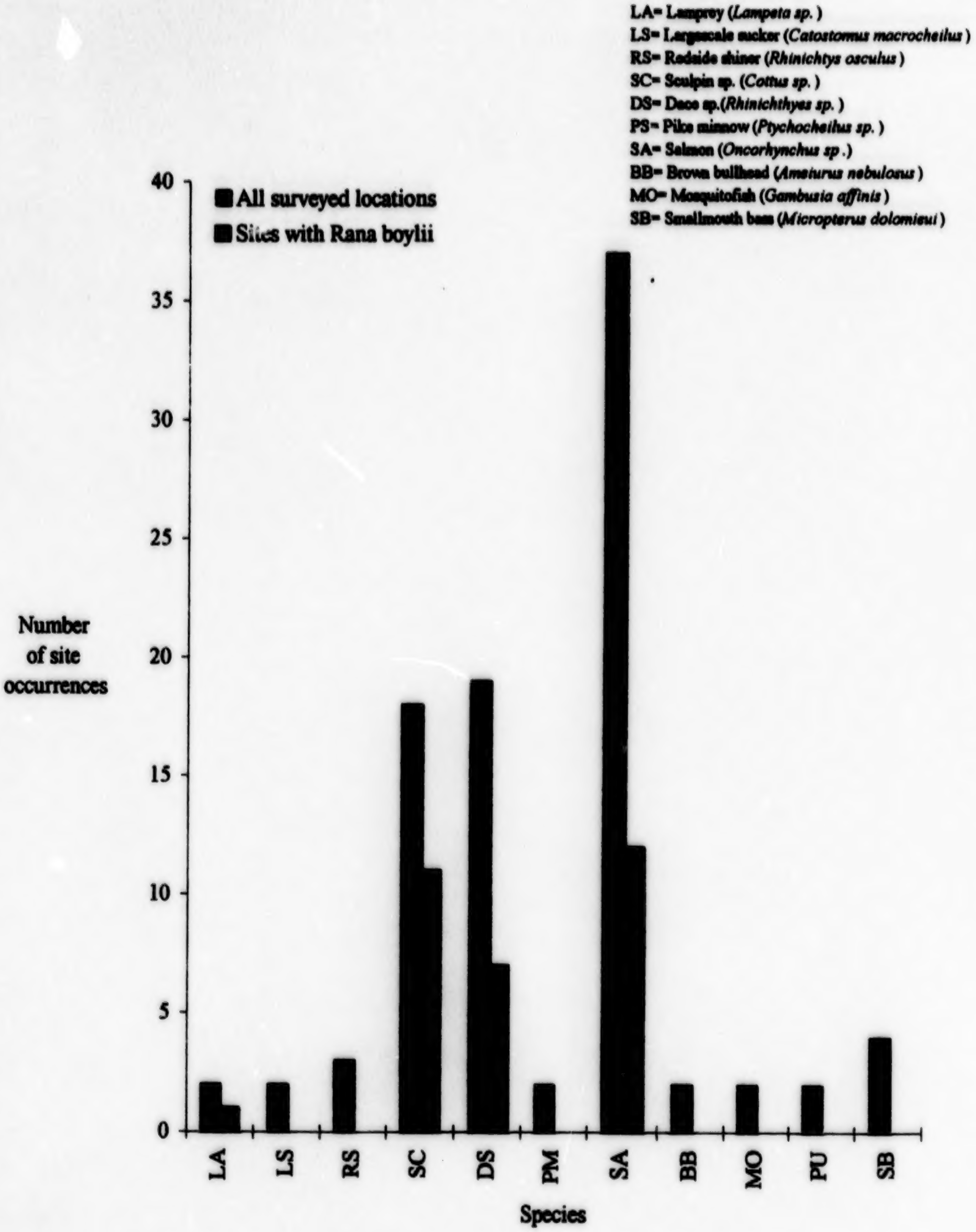

Figure 8. Fishes found at foothill yellow-legged frog sites

5.97, df = 1, p = 0.0145). Sculpins were seen at number of sites and probably represent several species. Likewise, salmonids were observed at over one third of all sites, and undoubtedly represent several species. Chinook salmon was identified based on two observations on the South Santiam (Willamette drainage; Site 2; Table 1) made during a 13 May 1998 survey: (1) an 820 mm fork length (FL) carcass was observed on a gravel bar being fed upon by 10 turkey vultures *(Cathartes aura)* on a gravel bar; and (2) a living, battered, fungus-laden individual (ca. 800+ FL) found a few hundred meters upstream from the carcass. Cutthroat trout identification was based on a single observation of dead ca. 350 mm FL fish, also from Site 2. One lamprey was observed during surveys at three sites, at Disston (Willamette drainage: Site 14), 0.25 mi east of Saunders Creek on Jerry Flat Road (Rogue drainage: Site 48), and on the North Fork of Deer Creek, 8 miles east of Roseburg (Umpqua drainage: Site 22)[4]. Pike minnows were observed at two sites. Umpqua pike minnows, identified from two dead 200-250 mm FL individuals, were seen in the Umpqua drainage at Site 20. Another pike minnow of unknown provenance was observed in the Rogue (Jumpoff Joe Creek: Site 67). Dace representing potentially more than one species were observed at over 20% of surveyed sites. Speckled dace were observed on the South Santiam (Site 2) and in the Klamath (below J.C. Boyle Reservoir; Site 104).

Smallmouth bass, the most often identified exotic fish, was observed at three localities in the Umpqua drainage (Elk Creek at Drain [Site 20] and 2 miles east of Elkton [Site 19], and at Myrtle Creek on the South Umpqua [Site 25]) and at one locality in the Willamette (South Santiam; Site 9) drainage. Smallmouths ranged in size from 50 to 300 mm FL and were observed foraging in shallow water (< 10 cm) close to shore (< 1 m). Brown bullhead, mosquitofish, and pumpkinseed were positively identified at two sites each.

Three species of aquatic reptiles were observed at historical foothill yellow-legged frog sites: Oregon garter snake (*Thamnophis atratus* [= *hydrophila*]), common garter snake (*T. sirtalis*), and western pond turtle (*Clemmys marmorata*). The Oregon garter snake was

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[4] The lamprey on the Row River may represent a separate taxon for the lampreys found at the other two sites. It was a ca. 200 mm individual with a fully developed oral disk, although it appeared to have the oral denticle pattern indicated for the Pacific lamprey.

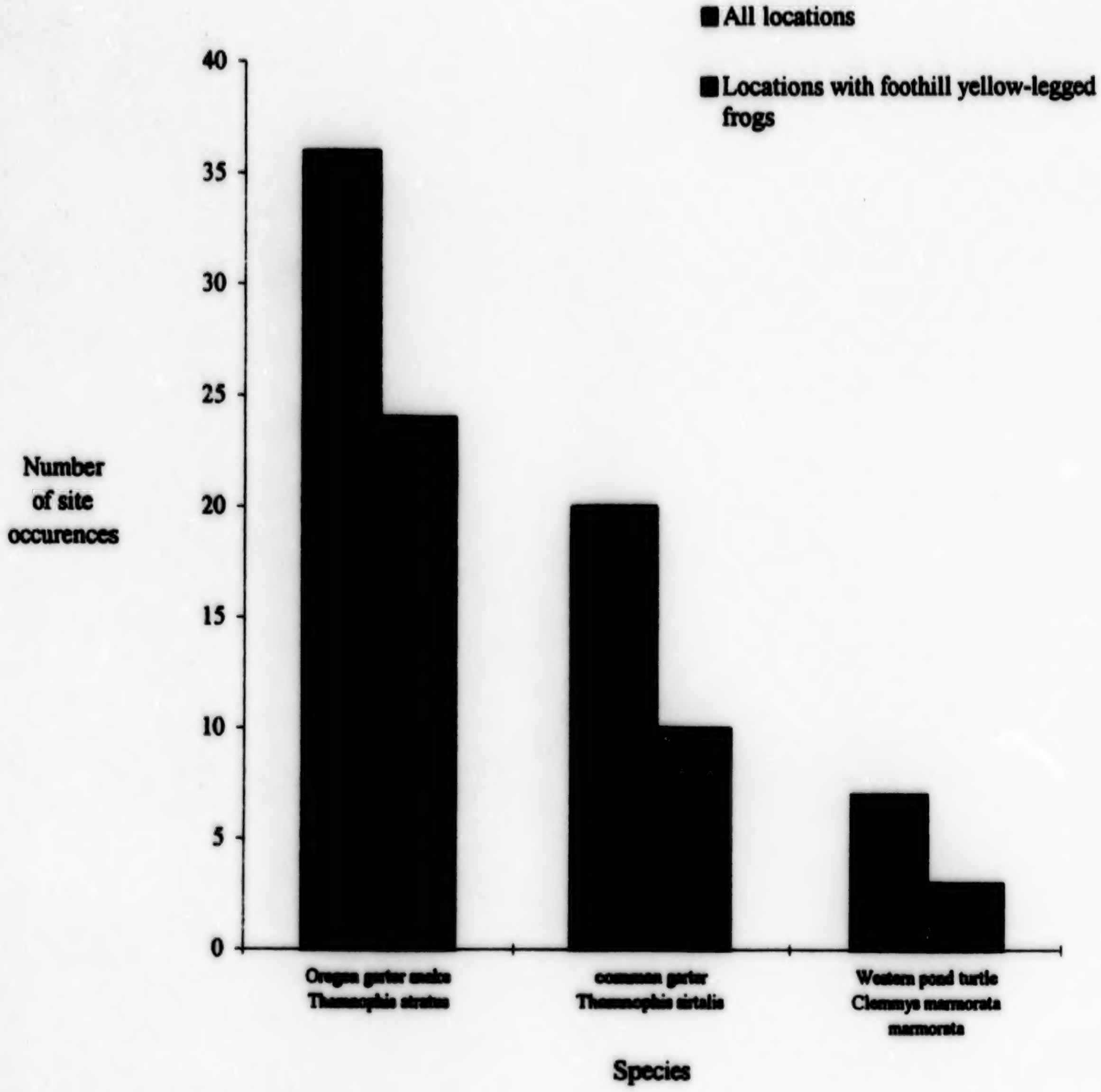

Figure 9. Aquatic reptiles found at historical foothill yellow-legged frog sites

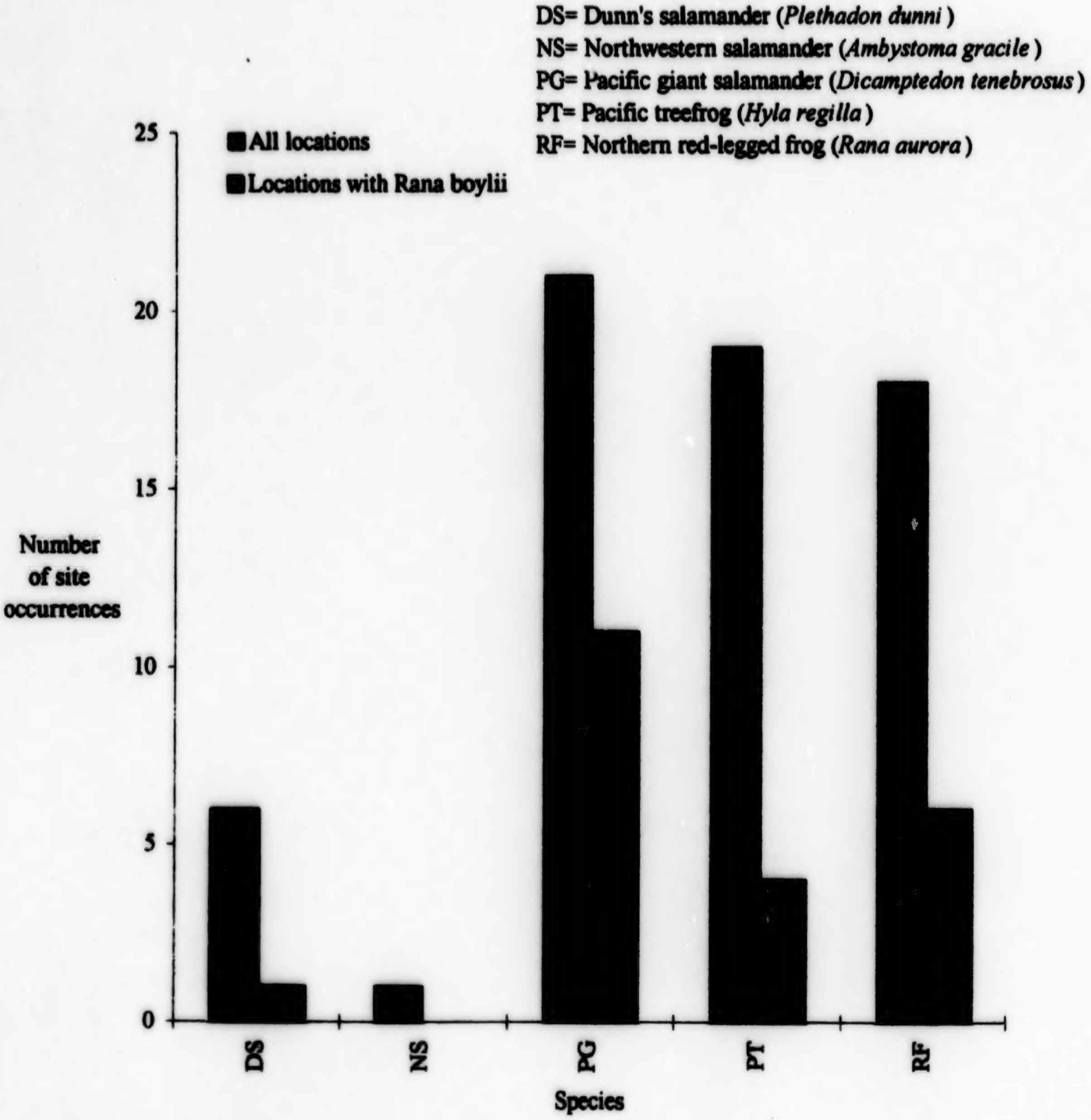

Figure 10. Amphibians found at historical foothill yellow-legged frogs sites

the most frequently observed reptile (Figure 9). Oregon garter snakes were observed at nearly two-thirds of the sites where yellow-legged frogs were found. Common garter snakes and western pond turtles were less frequently seen. One adult (> 400 mm snout-vent length) Oregon garter snake was observed feeding on a large (> 45 mm total length) foothhill yellow-legged frog tadpole.

Six species of aquatic or quasi-aquatic amphibians were observed at historical foothill yellow-legged frog sites (Figure 10): northwestern salamander (*Ambystoma gracile*), Pacific giant salamander (*Dicamptodon tenebrosus*), Pacific treefrog (*Hyla regilla*), Dunn's salamander (*Plethodon dunni*), northern red-legged frog (*Rana aurora aurora*), and rough-skinned newt (*Taricha granulosa*). Only the rough-skinned newt and the Pacific giant salamander were recorded at over one quarter of the sites with the foothill yellow-legged frog.

Watershed-specific data - Foothill yellow-legged frog status within primary watersheds varies considerably from the overall geographic pattern in the state. Pattern of distribution of foothill yellow-legged frogs across large watersheds was highly variable as were watershed-specific disturbance patterns and changes.

Brush Creek: Brush Creek was the first of four watersheds (with Hooskanadan, Myers, and Tuttle Creeks), all coastal in position, with very small (≤ 50 mi^2) basin areas. This drainage ranked 12th in size (10.0 mi^2) among the 15 primary drainages examined. One historical site was examined and the foothill yellow-legged frog was not found at that site (Figure 2). No exotics were observed at this site and no large impoundments were located on this system. The Brush Creek locality had little evidence of human disturbance other than the proximity of a state park on its lower reach. It had a low human disturbance score (23) and a low level of embeddeness. Only two types of human disturbance were recorded along Brush Creek: roads and recreation. Highway 101 lined the south bank of the stream for approximately one kilometer and the lower section of Brush Creek abutted Humbug State Park Campground with campsites present within four meters of the north bank. Brush Creek had low levels of embeddednes, but the reach was generally confined within typically steep (45°) banks.

30

Chetco River: The Chetco ranked 8th in size (630 mi^2) among the 15 primary drainages analyzed, and is one of four watersheds (with Coos, Coquille, and Smith) having a moderate-sized drainage area (> 500 mi^2 and ≤ 4,000 mi^2). Five historical foothill yellow-legged frog localities were sampled in the Chetco (Table 1), and foothill yellow-legged frogs were detected at four of the five (all except Joe Hall Creek: Site 46; Figure 2). Although the average human disturbance score at Chetco sites was relatively high (49.2), variability was high, ranging from a low of 21 (Long Ridge Forest Camp: Site 59) to a high of 88 (Chetco River Road: Site 56). Human disturbance of the landscape was predominantly timber harvest and recreation. Embeddness was also quite variable across sites, with values ranging from 0% to 55%. No exotics were recorded for any site, and large impoundments were absent from this system.

Coos River: The Coos ranked 7th in size (739 mi^2) among the 15 primary drainages analyzed, and is one of four watersheds (with the Chetco, Coquille, and Smith) having a moderate-sized drainage area (> 500 mi^2 and ≤ 4,000 mi^2). Only one historical foothill yellow-legged frog locality was examined in the Coos (S. Fork of Coos River at Marshfield: Site 36) and frogs were not detected at this site (Figure 2). This site was largely steep-banked silty glides and cattle grazed along the north bank over most of the reach[5]. This locality also had a moderately high human disturbance score (53), but no exotics were recorded. This system lacked large impoundments.

Coquille River: The Coquille ranked 5th in size (1,030 mi^2) among the 15 primary drainages analyzed, and is one of four watersheds (with the Chetco, Coos, and Smith) surveyed with a moderate-sized drainage area (> 500 mi^2 and ≤ 4,000 mi^2). Three historical foothill yellow-legged frog localities were examined in the Coquille and only one of three had frogs (Figure 2). The one site where yellow-legged frogs were found on the South Fork of the Coquille (Site 33) had numerous large boulders and small tributaries, and the main channel had a diversity of channel morphologies. This locality also had the lowest human disturbance score (29) of the three sites examined; the other two, the East Fork of the Coquille (Site 34) and Myrtle Point (Site 35) had disturbance scores of 44 and 72, respectively. Further, both Sites 34 and 35 had exotics (bullfrogs at both and brown bullhead at the latter) and a relatively homogeneous channel morphology. Site 34 had few gravel bars and open areas, lots of fine sediment and featureless bedrock, and generally well-vegetated banks. Site 35 site was highly embedded and the lower part of the reach smelled strongly of chlorine emanating from the nearby Myrtle Point sewage treatment plant. Downstream from the sewage discharge stream, the diversity of aquatic life appeared substantially reduced.

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[5] At Dellwood, a private Weyerhauser road provided the only access to the South Fork of the Coos River beyond that point for spot checks. Habitat for foothill yellow-legged frogs may improve above that point, but we were denied access. Our spot checks focused on the East and West Forks of the Millicoma, where the habitat was judged to be most suitable of the relatively limited habitat available for *Rana boylii*. We found two yellow-legged frogs along the West Fork of the Millicoma River.

Elk River: The Elk was the first of three watersheds (with the Pistol and Winchuck), all relatively coastal in position, with an area in the small size range (> 50 mi^2 and ≤ 500 mi^2). With a drainage basin area of 86.1 mi^2, it ranked 10th among the 15 primary drainages examined. Three historical localities were surveyed and foothill yellow-legged frogs were found at all three (Figure 2). Neither large impoundments nor aquatic exotic vertebrates were recorded for this system. Human disturbance scores were highly variable. The Elk had the lowest individual site and collective human disturbance scores of any drainage sampled (mean = 19; range: 14-22), and displayed embeddedness values of 0-40% (mean = 25%).

Hooskanadan Creek: Hooskanadan Creek was one of four watersheds (with Brush, Myers, and Tuttle Creeks), all coastal in position, with a very small (< 50 mi^2) basin area. This drainage ranked 14th in size (2.0 mi^2) among the 15 primary drainages analyzed. One historical site was examined and the foothill yellow-legged frog was not found at that site (Figure 2). No exotics were observed at this site and no large impoundments were located on this system. Hooskanadan had an intermediate human disturbance score (45), evidence of grazing and logging activities, and intermediate levels of embeddedness (40%).

Klamath River: The Klamath ranked 1st in size (15,500 mi^2) among the 15 primary drainages analyzed, and was one of four (with the Klamath, Umpqua, and Willamette), with a large drainage area (> 4,000 mi^2). However, a significant portion of this drainage area is in California. Despite its large size, historical foothill yellow-legged frog localities were restricted to a relatively small area that consisted of the mainstem Klamath River in the Klamath River Canyon and its nearby tributaries. Three historical localities were surveyed, and no foothill yellow-legged frogs were found at any of the three (Figure 2). Human disturbance scores were intermediate (mean = 40.6, range 31-48), but all localities were impoundment-influenced. Impoundments in California (Copco and Irongate Reservoirs) have isolated two of the three (Cottonwood [Site 95] and Jenny Creeks [Site 99]) sites, whereas J.C. Boyle Reservoir (in Oregon) has inundated the third (Site 104). Water levels downstream from J.C. Boyle Reservoir were observed to fluctuate over a meter in range during a five-hour period on 8 August 1998. Further, water downstream from J.C. Boyle Reservoir was visibly enriched. This was the only site where orthophosphate was found at a detectable level (> 1 ppm) among the 49 sites where it was sampled during 1997. Further, foam mats were observed along slow-moving sections of the entire reach and approximately 80 % of the speckled dace observed had fungus on their bodies. Additionally, bullfrogs were present at two of the three sites in the Klamath (95 and 104).

Pistol River: The Pistol was the second of three watersheds (with the Elk and Winchuck), all relatively coastal in position, with a small drainage area (> 50 mi^2 and ≤ 500 mi^2). With a drainage basin area of 96.3 mi^2, it ranked 9th among the 15 primary drainages examined. One historical foothill yellow-legged frog locality was surveyed and frogs were found at this site (Figure 2). Neither large impoundments nor aquatic exotic vertebrates were recorded for this system. The Pistol site had an intermediate human disturbances score (47) and was 70% embedded.

Smith River: The Smith ranked 6th in size (788 mi^2) among the 15 primary drainages analyzed, and is one of four watersheds (with the Chetco, Coos, and Coquille) having a moderate-sized drainage area (> 500 mi^2 and ≤ 4,000 mi^2). However, a significant portion of this drainage area is in California. One historical foothill yellow-legged frog locality was sampled in the Smith (Diamond Creek: Site 77), and foothill yellow-legged frogs were detected at this site (Figure 2). This locality also had the second lowest human disturbance score (17) of any site surveyed in this study. No exotics were recorded, and the embeddedness value were very low.

Myers Creek: Myers Creek was one of four watersheds (with Brush, Hooskanadan, and Tuttle Creeks), all coastal in position, with a very small (< 50 mi^2) basin area. This drainage ranked 13th in size (5.9 mi^2) among the 15 primary drainages analyzed. One historical site was examined and the foothill yellow-legged frog was not found at that site (Figure 2). No exotics were observed at this site and no large impoundments were located on this system. Myers Creek had a relatively low human disturbance score (< 35), but had fairly substantial evidence of timber harvest and fairly high levels of embeddness.

Rogue: The Rogue was 3rd in size (5,133 mi^2) among the 15 primary drainages surveyed, and was one of four (with the Klamath, Umpqua, and Willamette), with a large drainage area (> 4,000 mi^2). Foothill yellow-legged frogs were found at nearly half the localities (48.7% of n = 39) in the Rogue (Figure 2). In general, more detections were made across the Rogue as one moved from east to west. On the Applegate River (middle Rogue), frogs were detected at only 30% of 10 localities (n = 3). The dam at Applegate Lake isolates three historical foothill yellow-legged frogs localities in the upper watershed, yellow-legged frogs were detected at two of these three localities. We failed to detect frogs at the two localities in the mainstem Applegate River below Applegate Lake. By contrast, in the Illinois drainage (lower Rogue), which has no large impoundments, frogs were found at 80% of 10 localities (n = 8). However, intake pumps and gravel diversions to withdraw water for agricultural use were observed over most the survey area. Two localities where we failed to find frogs, Grayback and Sucker Creeks, had broad swaths along each bank that were unvegetated. The remainder of the Rogue, which included its mainstem and other minor tributaries scattered across the basin, had frogs at 42% of 19 localities (n = 8). Below the confluence with the Illinois River, bullfrogs were recorded at only one site, an artificial pond that blocking Libby Creek had created. Unimpounded waterways linked the remaining localities in the vicinity of the lower Rogue and foothill yellow-legged frogs were recorded at those sites. During surveys of the lower Rogue mainstem, commercial jet boats were observed to create substantial wakes that broke with considerable energy onshore; foothill yellow-legged frogs were not seen in these areas. We recorded jetboat passage every ca. 5 minutes during surveys. Wakes up to a meter high broke on shore.

Tuttle: With a drainage area of only 1.3 mi^2, Tuttle is the smallest of the four primary watersheds examined in this study with a very small (< 50 mi^2) drainage area and ranks last among the 15 primary drainages analyzed. One historical site was examined and the foothill yellow-legged frog was not found at that site (Figure 2). No exotics were observed at this site and no large impoundments were located on this system. Turtle Creek has a moderate human disturbance score (34) largely due to development and timber harvest along the reach. The Tuttle Creek drainage lacks large impoundments and exotics, and has intermediate levels of embeddedness. Accumulated human disturbances have left very little appropriate habitat for the foothill yellow-legged frogs to use. The lower reaches of the stream that may have had favorable gradients and substrates at one time were approximately 80% channelized or severely disturbed by other human activities.

Umpqua River: The Umpqua was 4th in size (4,640 mi^2) among the 15 primary drainages surveyed, was one of four (with the Klamath, Rogue, and Willamette), with a large drainage area (> 4,000 mi^2). Foothill yellow-legged frogs were detected at over one third of 12 sites (41.6%; n = 5) in the Umpqua. The Umpqua also exhibited variable patterns within the drainage. Along the North Umpqua, we found frogs at all three historic localities we surveyed (n = 3), but the South Umpqua watershed had yellow-legged frogs at only 40% of 5 localities (n = 2). We detected no frogs at the remainder of the minor lowland Umpqua tributaries surveyed, two localities on the Smith River and two on Elk Creek. Foothill yellow-legged frogs were also recorded incidentally at a single new locality, Whistlers Bend Campground east of Roseburg, which was not among historical localities surveyed.

Willamette River: The Willamette, 2nd in size (11,400 mi^2) among the 15 primary watersheds surveyed, was one of four (with the Klamath, Rogue, and Umpqua), with a large drainage area (> 4,000 mi^2). Foothill yellow-legged frogs were detected at only one locality (7.1% of n = 14) in the Willamette watershed (Figure 2). In the Willamette, 10 of the 14 historical localities are isolated (partially or fully) from the mainstem Willamette or its tributaries or inundated by reservoirs, namely Dorena, Foster, and Lookout Point. In general, Willamette drainage sites had intermediate to high human disturbance scores and levels of embeddedness, but some suitable habitat was lost through inundation (Figure 9a and 9b) or increased isolation of nearby sites was a by-product of inundation.

Winchuck: The Winchuck was the last of three watersheds (Elk, Pistol, and Winchuck), all relatively coastal in position, with areas in the small size range (> 50 mi^2 and ≤ 500 mi^2). With drainage basin area of 73.9 mi^2, it ranked 11th among the 15 primary drainages examined. Four historical foothill yellow-legged frog localities were surveyed and frogs were found at all four sites. Neither large impoundments nor aquatic exotic vertebrates were recorded for this system. Winchuck sites were variable in their human disturbances scores, ranging from a low of 25 to a high of 84 (mean = 56), In a similar pattern, embeddedness varied from 0% to 40% (mean = 26%).

Discussion

Our data imply a substantial reduction in the geographic range of *Rana boylii* in Oregon. Confidence in this finding is high because error associated lack of detection is low. Only four surveys of different sites revealed foothill yellow-legged frogs at sites where we had not recorded frogs during the first survey. Moreover, we interpret failure to detect frogs during two of these four surveys as due to survey dates that were slightly too early and too late in the seasonal interval to maximize detection. The number of frogs found at the other two of these four sites was low (≤ 4). This indicates that the likelihood of detecting frogs with the protocol we used is relatively high, and even if we had used only a single survey, we would have failed to detect only about 5% of the sites we found with frogs. It is, of course, possible that we failed to detect frog occurrence at very low levels ~~of~~ at some of the sites at which two surveys found no frogs. We cannot assess this situation without additional surveys, but the effort expended for detection at such low levels is probably not worth the effort.

Historically, data that address the relatively abundance of foothill yellow-legged frogs in Oregon are largely unavailable. Fitch (1936) discussed foothill yellow-legged frogs as being "common" or "abundant" at several sites in the Rogue watershed we visited that had no frogs present or where they were recorded in low numbers (< 10). Discussion with Dr. Fitch (pers. comm.) revealed that his assessment of "common" or "abundant" was likely numerically greater than the numbers we observed where we found yellow-legged frogs.

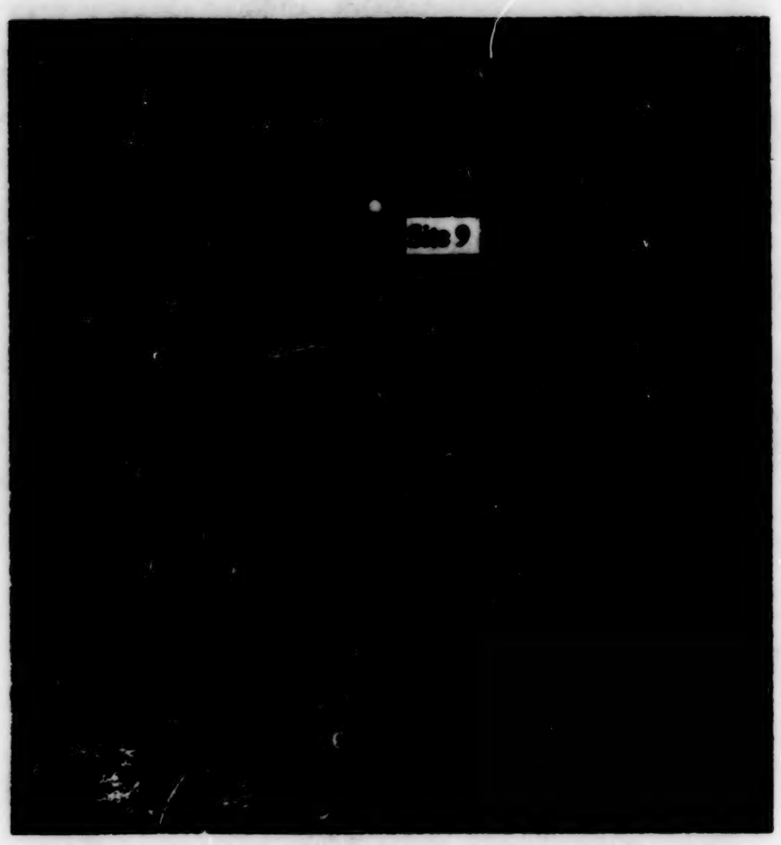

Figure 11a. South Santiam River in 1939 before Foster Reservoir was built

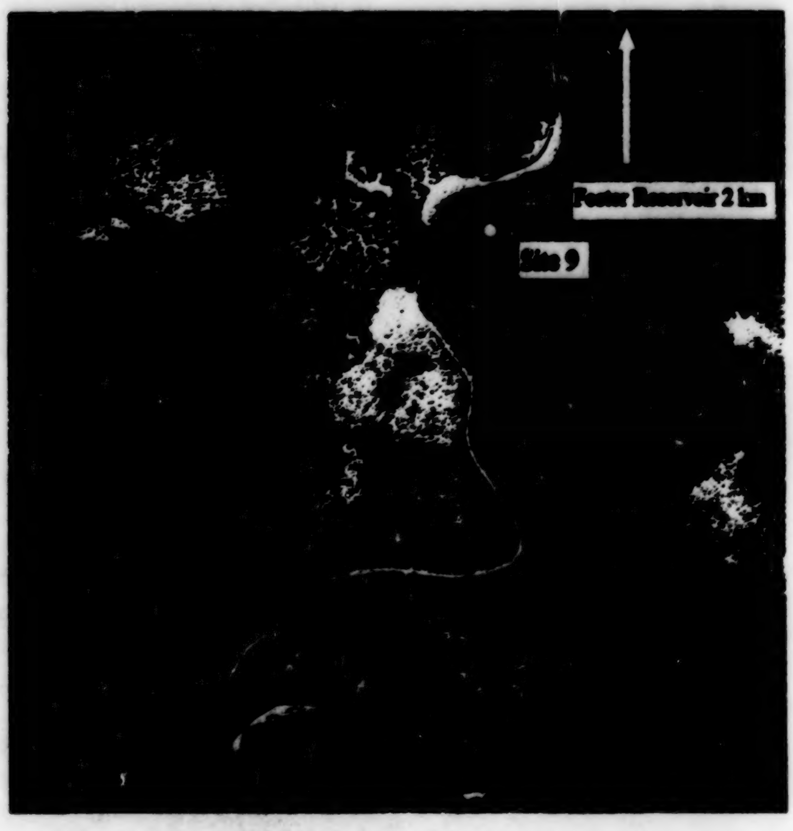

Figure11b.South Santiam river in 1991 after Foster Reservoir was built

Moreover, his narrative on this species across the Rogue gives the impression that this species was generally more common than ca. 60 years ago. Yet, comparison with his data provides, at best, a meager impression. Our inability to make any more than a very qualitative comparison underscores the importance and continuing need for baseline data that can be used to make historical comparisons.

Regardless of the paucity of historical data, our data reveal key patterns. **First**: A more frequent failure to record foothill yellow-legged frogs along northern and eastern margins of foothill yellow-legged frog geographic range in Oregon implies extirpation has been more frequent in these areas. Species are likely more resource or physical factor limited at the margins of their geographic ranges, and generally poor habitat conditions we observed in the range-margin basins (e.g., Klamath and Willamette) probably exacerbate limitations foothill yellow-legged frogs might experience in these areas.

Second: Consistent failure to detect foothill yellow-legged frogs in very small drainages (Brush, Hooskanaden, Myers, and Tuttle Creeks) may imply a high level of extirpation in such systems. These systems lacked large impoundments and exotics were not recorded in any of them, so impoundment-related habitat modifications (Lind et al. 1996) or negative effects that have been shown to be caused by exotic predators or competitors (Kupferberg 1996a, 1996b, 1997b) are probably not the causes of extirpation. Rather, the extent and quality of habitat for foothill yellow-legged frogs in these systems may be limited, which would make them vulnerable to natural catastrophic events. These systems were generally more shaded and had steeper bank slopes than the average among sites where we found foothill yellow-legged frogs. Steeper slopes and poorer insolation may limit basking sites, a important feature of yellow-frog habitat (Hayes and Jennings 1988, Jennings and Hayes 1994), and may make these drainages marginal habitat even though few disturbances exist of anthropogenic origin. Modifications that restrict basking may be particularly important in Oregon, which represents the northern third of the range of the foothill yellow-legged frog (Stebbins 1985). Natural disturbances, such as large magnitude high water events, similar to that observed in February 1996 in many drainages across southwestern Oregon and northwestern California, might have been enough to extirpate these frogs from these kinds of systems. Unfortunately, we lack before data to evaluate this hypothesis, so we do not know if some or any of these small drainages experienced locally extirpation as a result of the aforementioned event. Inability to evaluate this hypothesis adequately speaks to the need for consistent monitoring in addition having an adequate historical baseline.

If the aforementioned is true, the irony of this very small stream pattern is that lacking other alterations, high water events and strongly fluctuating water regimes may actually assist foothill yellow-legged frog populations in drainages in which selected exotic species have become established. Since yellow-legged frog larvae metamorphose after a relatively brief larvae interval and do not overwinter (Zweifel 1955), juvenile frogs can respond rapidly to unpredictable changes in flow. In contrast, bullfrog larvae in Oregon have to overwinter at least once before metamorphosis (Nussbaum et al 1983), which makes them vulnerable to high flow events in unaltered systems (Kupferberg 1996a, 1996b). High flows could also benefit yellow-legged frogs through bedload shifting and reestablishing the preferred coarse matrix in embedded systems if the altered pattern of excessive fine loading had been eliminated.

Third: Several elements in this study underscore the idea, suggested by Lind et al. (1996), that impoundments likely present a significant challenge for foothill yellow-legged frogs. First, the significantly lower frequency of yellow-legged frogs at sites downstream from large impoundments suggests an impoundment effect, a condition which is pronounced in the Willamette, but which also exists in the Applegate (Rogue) and Klamath drainages. Lind et al. (1996) and Kupferberg (1996a, 1996b, 1997b) have suggested four ways in which impoundments might affect foothill yellow-legged frogs negatively: (1) egg mass scour through aseasonal releases from the impoundment; (2) increased flow regulation, especially through the loss of crucial high water events, that decreases favorable (bar) habitat and promotes unfavorable (shaded-vegetated) habitat; (3) increased regulation of flow that favors instrusion of exotic competitors or predators (e.g., bullfrogs and warm-water fishes); and (4) increased flow regulation that favors increases in sedimentation of fines. To this list, we would add four additional mechanisms: (5) impoundments have the potential to fragment habitat connections between foothill yellow-legged frog population units; (6) impoundments have the ability to change downstream temperature patterns in a manner than may be unfavorable to foothill yellow-legged frogs, (7) impoundments can armor the substrate, or downcut or narrow the channel (Ligon et al. 1995; Mount 1995), and (8) impoundments can retain coarse substrates upstream and reduce the competence of the downstream channel to transport large substrate, all of which would degrade habitat for foothill yellow-legged frogs. Of the eight mechanisms, we cannot evaluate the first because we did not survey during the egg-laying interval, we cannot evaluate the sixth because we lack a temporal sequences of water temperature data for specific sites, we cannot evaluate the seventh because we lack "before" data on these structural features for the sites examined, and we cannot evaluate the eighth because we lack data on the coarse substrate retention abilities of existing impoundments. However, some of our data can address the other four. First, presentation of the aerial photointerpretation aspect of this study is beyond the scope of this report, but some preliminary observations suggest increases in riparian vegetation parallel to what Lind et al. (1996) encountered in the Trinity River (California) have occurred in at least three locations in the Willamette basin: (1) the North Santiam; (2) the South Santiam; and (3) the Middle Fork of the Willamette. Second, bullfrogs and exotic fishes were more frequently recorded below impoundments than at similar sites that were not impounded, which suggests that below-impoundment habitat is more favorable. Third, below-impoundment habitats were more embedded than similar reaches that were not impounded. Fourth, reservoirs have fragmented reaches of streams that were likely historically favorable for foothill yellow-legged frogs.

While one would probably not argue that impoundment effects are lacking, these data are remote from demonstrating that the observed effects really impinge on the foothill yellow-legged frog. A major difficulty is that habitat changes and exotic impacts are confounded. Further, lack of overlap between bullfrogs and foothill yellow-legged frogs may reflect habitat partitioning that may simply arise from the somewhat difference habitat conditions each species requires (Hayes and Jennings 1988; see also Moyle 1973). Iimpoundments may have created habitat conditions that disfavors foothill yellow-legged frogs while creating habitat more favorable for bullfrogs. These data cannot disentangle this scenario from one in which exotics have a direct effect (through competition or predation) on yellow-legged frogs.

Exotics (bullfrogs and perhaps warm-water fishes) have a demonstrated ability to put the yellow-legged frog at a competitive disadvantage (Kupferberg 1996a, 1996b, 1997b), a condition that has also been demonstrated for the northern red-legged frog (Kiesecker and Blaustein 1997), but whether that disadvantage has demographic recriminations remains to be demonstrated. Very recent data addressing northern red-legged frogs (Kiesecker and Blaustein 1998) suggests that an exotic fish (e.g., smallmouth bass) behaving as a selective agent may be required to translate the competitive advantage that bullfrog larvae gain over native frog larvae into a negative demographic consequence. Since smallmouth bass have recently expanded into portions of lowland western Oregon which has both bullfrogs and yellow-legged frogs present (e.g., the lower Umpqua system), this interaction has potential to have serious negative effects on the foothill yellow-legged frog.

Fourth: On a local scale, some habitat components important to yellow-legged frogs were altered or missing at many sites and may have contributed to their absence. However, the pattern of embeddedness of the coarse substrate matrix was a repeated theme generally correlated with the level of human disturbance, and irrespective of impoundment presence. Reasons for embeddedness include: (1) a reduction in the amount of coarse substrates, but particularly coarse gravels, bedrock and fine gravels, or (2) filling of the interstitial matrix in coarse substrates with fine materials (e.g., silt and sand).

Causes of embeddedness are complex because a suite of factors have the opportunity to do one or both the of above. Road building or timber harvest are well known to increase the sediment supply and can fill interstitial spaces in coarse substrates (Murphy et al 1981, Beschta 1987, Bilby 1985, Bilby et al. 1989, Welsh and Ollivier 1998) that foothill yellow-legged frog may use. Similarily, cattle grazing can destabilize banks, and increase erosion and sediment inputs (Kaufmann and Krueger 1984, Kaufmann et al. 1986). Quarrying for gravel can reduce coarse substrate loads because removal can exceed replenishment rates from upstream, and impoundments can block or diminish the passage of coarse substrates from upstream and diminish downstream competence (Mount 1995). A major difficulty in addressing causes of embeddedness is partitioning the sources in a manner that will allow determining the relative importance of contributors. Selected studies have attempted to determine relative contributions (e.g., Bilby et al. 1989), but large variation in even nearby sites generally requires that site-specific analyses be considered.

How sedimentation may adversely effect yellow-legged frogs life stages has not been studied, but several alternatives are possible: (1) embryos in egg masses may experience hypoxic or even anoxia conditions if fine loading impedes gas exchange; (2) the reduction or filling of interstitial spaces may reduce available refugia for tadpoles or juvenile stages, increasing the vulnerability of these stages to predators; (3) fine loading could favor the encroachment of vegetation that reduces basking or foraging habitat for postmetamorphic life stages, or foraging habitat for larval stages; and (4) fine loading could disfavor groups of invertebrates that are important elements of the prey base for postmetamorphic stages.

The high level of variability, both within and among watershed requires that we comment briefly on the dominant patterns in each.

Klamath watershed

Historically, the Klamath River included the furthest point east that foothill yellow-legged frogs were known to occur in Oregon. Failure to find foothill yellow-legged frogs at any of the Klamath localities agree with observations of poor habitat quality in this system.

John C Boyle Reservoir sits on the only the historic locality in Oregon on the Klamath mainstem. Some of the water from this reservoir enters an aqueduct that supplies a power station five miles downstream. Another portion flows out of a conduit into an artificial channel created by large boulders blasted from the surrounding rock. During summer months, increased diel demand flux in for electricity results in daily diversions into the aqueduct. This flux results in diel fluctuations in the water level of the Klamath mainstem of a meter or more (USGS 1996). Such rapid changes in water level and flow probably adversely affect foothill yellow-legged frog life stages, and particularly larvae, which could get washed away or stranded above the main channel (Kupferberg 1996a, 1996b).

Oregon Department of Environmental Quality data agree with our observations of poor water quality below J.C. Boyle Reservoir (Appendix IV). The water released below the dam is rich in total nitrogen and phosphate even though un-ionized ammonia levels of total ammonia do not attain values shown to be lethal to fish in the Klamath Basin National

Wildlife Refuge (Thurston et al 1981). Nevertheless, high pH episodes in combination with elevated total ammonia concentrations could rapidly raise the levels of un-ionized ammonia to levels that might be toxic to foothill yellow-legged frogs and could be a contributor to their absence during our surveys[6].

High levels of substrate fines and incised banks recorded at the remaining two Klamath localities may be linked to their absence of frogs at those localities, but the cause of this alteration at each site may be different. At Copco Springs, cattle were seen wandering the banks and in the stream whereas at Cottonwood Creek, a gravel road and railroad tracks paralleled most of the survey distance.

Umpqua watershed

The Umpqua does not face the kinds of problems that large-impoundment influenced as on the Willamette drainage. Status of yellow-legged frog appears better along the North Umpqua than along the South Umpqua. However, one historical locality at Steamboat on the North Umpqua (Tanner 1940) that was not addressed during current surveys and surveyed by one of us (MPH) in a manner parallel to the surveys we describe herein failed to reveal foothill yellow-legged frogs. Further, foothill yellow-legged frog adults and egg masses were observed as three new sites within the portion of the South Umpqua on the Tiller Ranger District (Umpqua National Forest) during other surveys in 1997-8. Thus, the asymmetry we describe based on the relative small samples between the North and South Umpqua may not be as great as the surveys here reflect. The condition that may differ significantly from the Willamette, especially in the mainstem Umpqua and lower reaches of the North and South Umpqua, is the relative abundance of smallmouth bass juxtaposed with bullfrogs. As this combination has been shown to be problematic for the northern red-legged frog (Kiesecker and Blaustein 1998), we anticipate it will probably pose a problem for the potentially more vulnerable (based on habitat use patterns) foothill yellow-legged frog.

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[6] Summer base flow and drought conditions exacerbate pH volatility because increases in sunlight and nutrients for photosynthesis. Superimposed on diel fluctuation in photosynthetic activity, ODEQ samples collected during the same month at different times of day demonstrate an increase in pH. Photosynthetic activity causes an increase in pH which can shift the equilibrium between ionized

Rogue watershed

Overall, the Rogue watershed had a substantial proportion of the most important habitat that remains for foothill yellow-legged frogs in Oregon. A high variability across the Rogue reflects different conditions in different areas.

Applegate: The pattern in the Applegate watershed is similar to that in the Willamette. The presence of Applegate Lake, a reservoir, creates parallel isolation and inundation in a substantial portion of the upper watershed. Localities where yellow-legged frogs still exist above the reservoir lack direct links to major drainages, making them susceptible to human disturbances such as suction dredge mining, and sedimentation from gravel access roads in the upper watershed. Regulated flow and temperature regimes likely influence localities downstream from Applegate Reservoir. Loss of the floodplain has reduced offchannel habitat along the mainstem, and a multi-port water intake system in Applegate Reservoir maintains cool water temperatures downstream throughout the summer for salmonids (Hubbard et al. 1994; USACE 1995). Offchannel habitat is important for rearing tadpoles, metamorphs and juveniles (Kupferberg 1996a). Artificially cooler temperatures have the potential to adversely affect the development of yellow-legged frog larvae by increasing the time required for metamorphosis (Kupferberg 1996b). Further downstream, intensive agriculture and cattle grazing decrease bank stability leading to increases in instream fine sediment loading (Kauffman et al. 1985; Allen 1995).

Illinois - The Illinois watershed contrast sharply with the Applegate through its lack of large impoundments. Retention of connectivity and a complex channel morphology are both relatively high in this system, and they may enable yellow-legged frogs to emigrate or find refuge from anthropogenic or other disturbances.

Two localities where we failed to find frogs, Grayback and Sucker Creeks, had evidence of extreme scour that probably represents the February 1996 high water event. However, we believe that the opportunity for recolonization of these sites is excellent because spot checks revealed yellow-legged frogs immediately downstream from both localities.

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ammonia and un-ionized ammonia towards un-ionized ammonia, which is toxic to organisms (Thurston et al 1981).

A potential threat to foothill yellow-legged frogs in the Illinois drainage is the demand for agricultural water. Desiccation in backwater pools and side channels has been identified as a cause of tadpole mortality (Storer 1925; Kupferberg 1996; Lind et al 1996). The large number of intake pumps and gravel diversions along many of the survey areas and a reduction in availability of water and dropping the water levels during the summer months could reduce available habitat for the species and increases the likelihood that tadpoles will be preyed upon or desiccate.

Mainstem Rogue and minor tributaries - Lost Creek Lake influences the upper Rogue above the Applegate River and its tributaries. Lost Creek dam does not isolate historical localities in the upper system from each other, but regulated flow downstream may alter the habitat in a manner more favorable to bullfrogs (seen Kupferberg 1996b) and probably exotic fishes. Conditions deemed favorable to foothill yellow-legged frogs improve below the confluence with the Illinois River. Yellow-legged frogs exhibit a high occupancy in a matrix of linked, unimpounded waterways.

Along the lower mainstem, selected recreational activities may, over time, adversely affect yellow-legged frogs. During spring and summer, commercial jet boats pound the shoreline with wakes that break with considerable energy. Continual shoreline disruption from boat traffic may force the yellow-legged frogs off the banks, reducing basking time and making them potentially more susceptible to predation. Incidental jet boat wakes may also cause erosional changes that create unfavorable shoreline conditions for foothill yellow-legged frogs. Furthermore, recreators that drive vehicles out onto gravel bars to fish, swim or camp probably create additional, but unknown levels of disturbance. Yellow-legged frogs typically respond to approach by diving into the water, often swimming under a rock. Recreators could reduce basking time through continual disruption, a condition that has unknown but probably negative effects.

Willamette watershed

Generally high levels of disturbance (including exotic aquatic predators or competitors), most localities being directly or indirectly influenced by impoundments, and presumptive local water quality problems place foothill yellow-legged frogs at high risk of extirpation in the Willamette watershed. Suitable habitat loss through inundation is the obvious direct effect, but population isolation through restriction or elimination of aquatic corridors may be a more insidious effect. Frogs historically at least had some opportunity for connection through aquatic corridors. In fact, the mainstems of all Willamette subbasins historically harboring the yellow-legged frog except the McKenzie River are cut off from each other by major impoundments (see Appendix IVa-IVb). An increase in patch isolation decreases opportunities for immigration, and opportunities for colonizations by local populations to rescue extant populations in other areas (Blaustein et al 1994). Collectively, this increases the likelihood of extirpation.

Small primary drainages (Elk, Pistol, and Winchuck)

Except for some of the lower Pistol River, which was grazed and fine-substrate dominated, these were the least disturbed drainages surveyed. These are the drainages that may be the closest to approximating a historic reference condition for the foothill yellow-legged frog in Oregon. No impoundments and exotics, and low human disturbance scores appear to give these drainages the closest to ideal combination of flow regimes and substrate characteristics for the life stages foothill yellow-legged frogs.

Moderate-sized primary drainages (Chetco, Coquille, Coos, Smith)

This series of drainages shows a high degree of variability. The southern pair (Chetco and Smith) display considerably higher quality habitat, some of which matches the presumed historic reference condition observed in the previously discussed smaller streams (e.g., Elk, Pistol, and Winchuck). The northern pair displays a high degree of natural variability that ranges from qualitatively poor foothill yellow-legged frog habitat (e.g., East Fork of the Coquille) to high quality foothill yellow-legged frog habitat (e.g., South Fork of the Coquille).

Very small primary drainages (Brush, Hooskanadan, Myers, Tuttle)

This drainages were previously addressed under the second point in the discussion.

Conclusion

The study revealed that the foothill yellow-legged frog has conservatively sustained a roughly 50% reduction in its geographic range in Oregon. Although we are confident in this result, this assessment needs verification as the sites surveyed, the historical locations, represent but a subset of the sites at which the foothill yellow-legged frog might occur across its Oregon range. In particular, surveys should be focused on the intercalated areas among the historical locations to: (1) determine all localities where Oregon spotted frogs still remain; and (2) identify the precise pattern distribution in the remaining range.

Although the Oregon range of the foothill yellow-legged frog still remains incompletely known, the study reveals some patterns that have a significant conservation bearing. The first is that large impoundments probably substantially alter habitat for this species. For this reason, conservation of the relatively few unimpounded systems in that state should be the highest priority. Impoundments have a high likelihood of changing the hydrology and geomorphology of the system that will degrade habitat for the foothill yellow-legged frog. Since these hydrological-geomorphological alterations represent fundamental changes in the functioning of these systems, a high likelihood exists that suites of species dependent on these systems in addition to yellow-legged frogs are negatively affected. It also needs emphasis that this is a pattern that needs substantially greater study. However, at this interim stage, the highest conservation efforts should be focused on those unimpounded systems that are thought to be closest to the reference condition. We view the Chetco, Elk, Pistol, Winchuck, and Smith as the highest priority drainages, with the Elk and Smith in the topmost tier, and a second high priority tier would include the Illinois (Rogue) and the upper portion of the South Umpqua (above Tiller). A second, very different, but equally high priority conservation effort should address those systems with populations at greatest risk. These are the systems in greatest need of more comprehensive survey because few or no populations were detected during our systems. Remaining populations in these systems (if any exist), are regarding at the highest risk of extinction. The Oregon portion of the Klamath Basin and the Willamette hydrographic basin should be topmost priorities here. A second tier of systems should include the Applegate (Rogue), the Coos, and the Coquille.

Many of the causal bases of the contraction in geographic range that the foothill yellow-legged frog has sustained remain to be determined precisely, but this study revealed habitat changes, especially those influencing substrate structure, that are likely a prominent part of the basis of this reduction. As previous noted, many kinds of habitat changes can modulate changes in substrate structure in a manner that might negatively affect foothill yellow-legged frogs. However, this study suggests that impoundments and grazing are potential causal elements worthy of detailed investigation. That aseasonal releases can scour yellow-legged frog egg masses and alteration of the hydrological regime can create unfavorable habitat conditions has already been demonstrated for one system with a large impoundment (Lind et al. 1996). The variability of impoundments and, in particular, the variability in their manner of altering the hydrological regime (Ligon et al. 1995) requires that effort be devoted to studying impoundment-specific changes in context of potential effects on the foothill yellow-legged frog. Further, the presumptive negative effect of an increase in substrate fines, a prominent pattern in this study, is suspected to function by reducing refuges for foothill yellow-legged frog life stages. That link has never been experimentally addressed and deserves study. In contrast, grazing patterns, which may be equally variable, have never been studied in the context of their potential negative effects on foothill yellow-legged frogs. Since grazing is a prominent aspect of landscape ecology over much of the range of the yellow-legged frog, this pattern deserves study.

Beyond these more prominent elements, the potential effects of predators, namely bullfrogs and smallmouth bass, need study to disentangle them from effects of habitat alteration that disfavor foothill yellow-legged frogs but favor exotics. Recent examination of northern red-legged frogs in the aforementioned context (Kiesecker and Blaustein 1998) implies that three-way studies involving bullfrogs, exotic fish, and native anurans would reveal more definitive answers. However, all existing studies fall short of definitive conclusions about the causal basis of native anuran extirpations in a region-specific context because of lack of linkage between experiments and observed patterns in the field. The latter will require no small effort, as translation of an experimentally determined effect to a significant demographic consequence is a high cost

Selected aspects of this study also imply that water quality issues in which ammonia and pH are prominent deserve study. Unfortunately, no satisfactory basis exists for predicting what may emerge from such a study in the context of foothill yellow-legged frogs.

Although the causal bases of reduction of foothill yellow-legged frog geographic range are not definitively established, the data from this study can provide some guidance to foothill yellow-legged frog conservation. These suggestions can be refined as studies of the aforementioned area are completed. These suggestions address four areas:

(1) Minimize alterations that load substrate fines in excess of their natural removal patterns. Obviously, this covers a broad area that includes excessive loading as a consequence of selected alterations of the hydrological regime because of impoundments, grazing, quarrying, road building, timber harvest, and other factors. Thresholds above which excessive loading of substrate fines occurs will have to be defined on hydrology- and reach-specific bases.

(2) Minimize alterations that make the stream-edge habitat unfavorable to foothill yellow-legged frogs. This also covers a broad area that touches on most altering factors mentioned in (1). Specific ways in which alteration can be minimized are factor-specific. For example, much of the negative effect of grazing may be attenuated by off-channel watering of livestock combined with fencing that excludes direct access to the channel.

(3) Minimize alterations that favor exotics potentially detrimental to foothill yellow-legged frogs. This would include alternatives that allow maintenance or promote expansion of existing yellow-legged frog populations as well as excluding novel introductions. For example, avoiding alterations that dampen the hydrological regime probably suppresses existing exotics by encouraging conditions that at least periodically reduce the number of the latter.

(4) Minimize alterations that degrade water quality for foothill yellow-legged frogs. Since water quality standards for foothill yellow-legged frogs have not been defined, threshold values will have to be established by life stage-specific studies. Because threshold values above or below which negative effects on foothill yellow-legged frogs can be identified have not been established for most chemical parameters, guidelines to minimize alterations should be conservatively applied.

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Appendix I. Substrate characteristics for primary and secondary watersheds.

"Primary" indicates watersheds which drain directly to the coast with exception for the Willamette which drains into the Columbia river. "Secondary" indicates watersheds which flow into primary watersheds. "BDT" is the total bedrock count for each site. "BLT"is the total bedrock count for each site. "CBT" is the total cobble count for each site. "CGT" is the total coarse gravel count for each site. "FGT" is the total fine gravel count for each site. "SAT" is the total sand count for each site. "SIT" is the total silt count for each site. "Total" is the total count of all substrate categories at each site. Columns adjacent to the total counts are the relative percentage for substrate in each category.

WATERSHED		SUBSTRATE														
PRIMARY	SECONDARY	BDT	BD%	BLT	BL%	CBT	CB%	CGT	CG%	FGT	FG%	SAT	SA%	SIT	SI%	TOTAL
Brush Creek		0	0	0	0	0	0	3	43	2	29	2	29	0	0	7
Chetco River		0	0	2	5	5	12	21	50	3	7	5	12	6	14	42
Chetco River		2	3	10	17	7	12	21	36	3	5	10	17	6	10	59
Chetco River		6	10	0	0	8	14	37	63	6	10	2	3	0	0	59
Chetco River	Joe Hall Creek	1	5	2	11	3	16	4	21	2	11	3	16	4	21	19
Chetco River	South Fork Chetco River	7	37	0	0	2	11	5	26	2	11	2	11	1	5	19
Coos River	South Fork Coos	0	0	14	35	3	8	0	0	0	0	0	0	23	58	40
Coquille River	East Fork Coquille River	13	26	14	28	4	8	3	6	1	2	5	10	10	20	50
Coquille River	South Fork Coquille River	2	4	39	68	6	11	4	7	3	5	3	5	0	0	57
Coquille River	South Fork Coquille River	0	0	5	9	1	2	2	4	2	4	9	17	35	65	54
Elk River		6	60	0	0	3	30	0	0	1	10	0	0	0	0	10
Elk River		22	40	2	4	4	7	16	29	6	11	3	5	2	4	55
Elk River		17	31	12	22	2	4	17	31	6	11	0	0	1	2	55
Hooskanaden Creek		17	33	9	17	6	12	10	19	5	10	3	6	2	4	52
Klamath River	Cottonwood Creek	5	10	5	10	7	15	13	27	7	15	7	15	4	8	48
Klamath River	Jenny Creek	1	3	3	10	7	23	9	30	4	13	2	7	4	13	30
Klamath River		0	0	49	91	3	6	1	2	0	0	0	0	1	2	54
Myers Creek		0	0	12	26	8	17	13	28	8	17	3	6	3	6	47
Pistol River		0	0	1	2	3	6	24	50	7	15	4	8	9	19	48
Rogue River	Antelope Creek	0	0	0	0	5	14	15	41	7	19	3	8	7	19	37
Rogue River	Applegate River	9	24	0	0	0	0	7	18	7	18	3	8	12	32	38
Rogue River	Applegate River	14	24	6	10	8	14	16	27	6	10	8	14	1	2	59
Rogue River	Applegate River	0	0	14	24	4	7	19	32	11	19	2	3	9	15	59
Rogue River	Applegate River	6	13	2	4	5	10	15	31	3	6	6	13	11	23	48
Rogue River	Applegate River	12	23	10	19	12	23	5	9	6	11	7	13	1	2	53
Rogue River	Applegate River	3	7	5	11	13	30	16	36	4	9	1	2	2	5	44
Rogue River	Applegate River	14	26	3	6	11	21	12	23	1	2	8	15	4	8	53
Rogue River	Applegate River	1	2	6	13	9	19	16	34	4	9	0	0	11	23	47
Rogue River	Applegate River	5	9	3	5	11	20	25	45	8	15	0	0	3	5	55
Rogue River	Applegate River	14	28	13	26	11	22	7	14	4	8	1	2	0	0	50
Rogue River	Bear Creek	4	11	0	0	12	32	4	11	3	8	8	21	7	18	38
Rogue River	Bear Creek	3	9	0	0	5	14	9	26	8	23	6	17	4	11	35
Rogue River	Bear Creek	2	15	0	0	1	8	8	62	1	8	0	0	1	8	13
Rogue River	Elk Creek	11	23	4	8	17	35	6	13	5	10	1	2	4	8	48
Rogue River	Evans Creek	15	33	5	11	2	4	3	7	0	0	3	7	18	39	46
Rogue River	Graves Creek	9	18	11	22	10	20	14	29	3	6	0	0	2	4	49
Rogue River	Illinois River	2	14	1	7	1	7	3	21	0	0	3	21	4	29	14
Rogue River	Illinois River	8	16	0	0	4	8	26	52	4	8	6	12	2	4	50
Rogue River	Illinois River	13	65	0	0	4	20	1	5	1	5	1	5	0	0	20
Rogue River	Illinois River	5	25	4	20	6	30	2	10	3	15	0	0	0	0	20
Rogue River	Illinois River	0	0	1	2	19	39	17	35	6	12	4	8	2	4	49
Rogue River	Illinois River	0	0	0	0	3	15	11	55	3	15	2	10	1	5	20
Rogue River	Illinois River	0	0	1	6	4	24	10	59	0	0	2	12	0	0	17

WATERSHED		SUBSTRATE														
PRIMARY	SECONDARY	BDT	BD%	BLT	BL%	CBT	CB%	CGT	CG%	FGT	FG%	SAT	SA%	SIT	SI%	TOTAL
Rogue River	Illinois River	2	11	5	28	4	22	3	17	2	11	2	11	0	0	18
Rogue River	Illinois River	1	7	0	0	2	13	2	13	3	20	7	47	0	0	15
Rogue River	Illinois River	4	7	0	0	9	16	17	30	8	14	5	9	14	25	57
Rogue River	Jim Hunt Creek	0	0	0	0	1	2	22	47	5	11	0	0	19	40	47
Rogue River	Jumpoff Joe Creek	11	22	0	0	6	12	11	22	4	8	13	25	6	12	51
Rogue River	Kimball Creek	5	9	7	13	6	11	24	43	10	18	4	7	0	0	56
Rogue River	Libby Creek	3	7	4	9	3	7	17	39	10	23	0	0	7	16	44
Rogue River		22	40	22	40	4	7	2	4	3	5	1	2	1	2	55
Rogue River		2	20	0	0	0	0	4	40	2	20	1	10	1	10	10
Rogue River		34	63	7	13	1	2	1	2	1	2	7	13	3	6	54
Rogue River		19	33	20	34	5	9	12	21	2	3	0	0	0	0	58
Rogue River		20	33	11	18	3	5	12	20	4	7	4	7	6	10	60
Rogue River	Trail Creek	8	16	6	12	11	22	14	28	1	2	8	16	2	4	50
Rogue River	Trail Creek	25	47	4	8	5	9	12	23	3	6	4	8	0	0	53
Rogue River	Unnamed trib. to Rogue River	0	0	1	4	1	4	8	30	5	19	2	7	10	37	27
Smith River	Diamond Creek	13	31	14	33	9	21	4	10	2	5	0	0	0	0	42
Tuttle Creek	Tuttle Creek	2	29	0	0	1	14	0	0	2	29	0	0	2	29	7
Umpqua River	Elk River	1	2	0	0	2	4	7	15	0	0	3	6	35	73	48
Umpqua River	Elk River	7	15	5	11	3	6	9	19	3	6	15	32	5	11	47
Umpqua River	North Umpqua River	8	20	1	3	8	20	6	15	4	10	0	0	13	33	40
Umpqua River	North Umpqua River	34	59	9	16	4	7	5	9	1	2	5	9	0	0	58
Umpqua River	North Umpqua River	5	9	11	20	12	22	26	47	1	2	0	0	0	0	55
Umpqua River	Smith River	31	58	4	8	1	2	2	4	2	4	4	8	9	17	53
Umpqua River	Smith River	19	34	7	13	4	7	11	20	3	5	9	16	3	5	56
Umpqua River	South Umpqua River	5	11	3	6	10	21	17	36	3	6	0	0	9	19	47
Umpqua River	South Umpqua River	9	18	0	0	1	2	10	20	8	16	13	27	8	16	49
Umpqua River	South Umpqua River	12	26	3	6	3	6	12	26	1	2	5	11	11	23	47
Umpqua River	South Umpqua River	1	2	16	39	1	2	5	12	1	2	10	24	7	17	41
Umpqua River	South Umpqua River	19	46	3	7	4	10	5	12	2	5	2	5	6	15	41
Willamette River	Coast Fork Willamette River	26	50	4	8	6	12	10	19	5	10	1	2	0	0	52
Willamette River	Coast Fork Willamette River	9	18	15	29	11	22	8	16	1	2	2	4	5	10	51
Willamette River	McKenzie River	0	0	0	0	12	28	15	35	8	19	1	2	7	16	43
Willamette River	Middle Fork Willamette River	4	10	4	10	8	20	20	49	0	0	1	2	4	10	41
Willamette River	Middle Fork Willamette River	3	7	8	20	9	22	16	39	2	5	0	0	3	7	41
Willamette River	Middle Fork Willamette River	20	35	15	26	4	7	13	23	1	2	3	5	1	2	57
Willamette River	Middle Fork Willamette River	3	7	12	26	12	26	11	24	6	13	2	4	0	0	46
Willamette River	North Fork Santiam	11	20	12	22	15	27	9	16	2	4	3	5	3	5	55
Willamette River	South Fork Santiam	8	22	0	0	12	33	6	17	0	0	6	17	4	11	36
Willamette River	South Fork Santiam	28	61	4	9	4	9	4	9	4	9	1	2	1	2	46
Willamette River	South Fork Santiam	31	63	6	12	6	12	1	2	2	4	2	4	1	2	49
Willamette River	South Fork Santiam	31	53	9	16	6	10	7	12	2	3	3	5	0	0	58
Willamette River	South Fork Santiam	32	70	5	11	5	11	1	2	0	0	0	0	3	7	46
Willamette River		0	0	1	5	1	5	4	20	1	5	0	0	13	65	20
Winchuck River		14	25	2	4	16	28	15	26	3	5	1	2	6	11	57
Winchuck River		6	11	3	5	5	9	29	53	5	9	7	13	0	0	55
Winchuck River		9	47	1	5	2	11	3	16	3	16	1	5	0	0	19
Winchuck River		19	35	5	9	10	19	17	31	3	6	0	0	0	0	54

Appendix II. Channel morphology characteristics for primary and secondary watersheds.

"Primary" indicates watersheds which drain directly to the coast with exception for the Willamette which drains into the Columbia river. "Secondary" indicates watersheds which flow into primary watersheds. "FA" is the total falls count at each site. "CA"is the total cascades count for each site. "RA" is the total rapids count for each site. "RI" is the total riffles for each site. "GL" is the total glides count for each site. "PT" is the total pools count for each site. "DR" is the total dry channel count for each site. "Total" is the total channel unit count for each site. "Percent Fast" is the percentage of FA, CA, RA and RI at each site. "Percent Slow" is the percentage of GL and PL and each site. Columns adjacent to the total counts in each category are the percentage for categories at each site.

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WATERSHED		CHANNEL UNIT COUNTS AND PERCENTAGES																
PRIMARY	SECONDARY	FA	FA%	CA	A%	RA	RA%	RI	RI%	GL	GL%	PT	PT%	DR	DR%	TOTAL	FAST%	SLOW%
Brush Creek		•	•	•	•	2	20	6	60	1	10	1	10	0	•	10	80	20
Chetco River	Joe Hall Creek	1	7	•	•	1	7	7	47	2	13	4	27	0	•	15	60	40
Chetco River	South Fork Chetco River	4	20	6	30	•	•	3	15	•	•	7	35	0	•	20	65	35
Chetco River		•	•	•	•	•	•	3	15	10	50	7	35	0	•	20	15	85
Chetco River		•	•	•	•	•	•	4	20	10	50	6	30	0	•	20	20	80
Chetco River		•	•	•	•	1	5	2	11	8	42	8	42	0	•	19	16	84
Coos River	South Fork Coos	•	•	•	•	•	•	0	0	19	100	0	0	0	•	19	0	100
Coquille River	East Fork Coquille River	•	•	•	•	3	15	5	25	7	35	5	25	0	•	20	40	60
Coquille River	South Fork Coquille River	•	•	1	6	4	22	7	39	3	17	3	17	0	•	18	67	33
Coquille River	South Fork Coquille River	•	•	•	•	•	•	1	6	16	89	1	6	0	•	18	6	94
Elk River	Panther Creek	•	•	1	10	2	20	4	40	2	20	1	10	0	•	10	70	30
Elk River		•	•	•	•	1	5	2	10	12	60	5	25	0	•	20	15	85
Elk River		•	•	6	32	3	16	4	21	•	•	3	16	3	16	19	81	19
Hooskanaden Creek		2	10	6	30	3	15	3	15	•	•	6	30	0	•	20	70	30
Klamath River	Cottonwood Creek	•	•	1	5	•	•	7	37	5	26	6	32	0	•	19	42	58
Klamath River	Jenny Creek	•	•	1	5	5	25	9	45	4	20	1	5	0	•	20	75	25
Klamath River		•	•	1	5	3	15	8	40	3	15	5	25	0	•	20	60	40
Myers Creek		•	•	•	•	6	32	7	37	1	5	5	26	0	•	19	68	32
Pistol River		•	•	•	•	1	5	1	5	18	90	0	0	0	•	20	10	90
Rogue River	Antelope Creek	•	•	•	•	•	•	8	40	8	40	4	20	0	•	20	40	60
Rogue River	Applegate River	•	•	•	•	3	15	2	10	12	60	3	15	0	•	20	25	75
Rogue River	Applegate River	•	•	2	10	6	30	9	45	1	5	2	10	0	•	20	85	15
Rogue River	Applegate River	•	•	•	•	•	•	2	10	•	•	18	90	0	•	20	10	90
Rogue River	Applegate River	•	•	•	•	1	5	7	35	7	35	5	25	0	•	20	40	60
Rogue River	Applegate River	•	•	2	10	3	15	15	75	•	•	0	0	0	•	20	100	0
Rogue River	Applegate River	•	•	1	5	4	20	10	50	•	•	5	25	0	•	20	75	25
Rogue River	Applegate River	1	5	•	•	8	40	8	40	1	5	2	10	0	•	20	85	15
Rogue River	Applegate River	•	•	•	•	•	•	3	16	7	37	8	42	1	5	19	17	83
Rogue River	Applegate River	•	•	•	•	11	55	9	45	•	•	0	0	0	•	20	100	0
Rogue River	Applegate River	•	•	3	15	10	50	3	15	1	5	3	15	0	•	20	80	20
Rogue River	Bear Creek	•	•	•	•	8	44	9	50	1	6	0	0	0	•	18	94	6
Rogue River	Bear Creek	•	•	2	10	10	50	5	25	2	10	1	5	0	•	20	85	15
Rogue River	Bear Creek	•	•	•	•		•	6	60	1	10	2	20	1	10	10	67	33
Rogue River	Elk Creek	•	•	•	•	2	10	1	5	16	80	1	5	0	•	20	15	85
Rogue River	Evans Creek	•	•	•	•	5	26	8	42	6	32	0	0	0	•	19	68	32
Rogue River	Graves Creek	•	•	2	10	5	25	9	45	•	•	4	20	0	•	20	80	20
Rogue River	Illinois River	•	•	1	5	3	16	2	11	4	21	9	47	0	•	19	32	68
Rogue River	Illinois River	•	•	•	•	•	•	1	5	12	60	7	35	0	•	20	5	95
Rogue River	Illinois River	1	5	1	5	6	30	3	15	2	10	7	35	0	•	20	55	45
Rogue River	Illinois River	3	15	2	10	1	5	7	35	1	5	6	30	0	•	20	65	35
Rogue River	Illinois River	•	•	•	•	8	53	5	33	1	7	1	7	0	•	15	87	13
Rogue River	Illinois River	•	•	•	•	2	11	7	37	9	47	1	5	0	•	19	47	53
Rogue River	Illinois River	•	•	1	5	11	55	7	35	•	•	1	5	0	•	20	95	5
Rogue River	Illinois River	•	•	2	10	8	40	8	40	•	•	2	10	0	•	20	90	10

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Kiesecker, J.M
smallmouth
(*Rana aur*

Kupferberg, J.S
garter snak
25(3):95-9

WATERSHED		CHANNEL UNIT COUNTS AND PERCENTAGES																
PRIMARY	SECONDARY	FA	FA%	CA	A%	RA	RA%	RI	RI%	GL	GL%	PT	PT%	DR	DR%	TOTAL	FAST%	SLOW%
Rogue River	Illinois River	•	•	•	•	6	30	11	55	•	•	3	15	0	•	20	85	15
Rogue River	Illinois River	•	•	•	•	1	5	7	35	9	45	3	15	0	•	20	40	60
Rogue River	Jim Hunt Creek	•	•	•	•	•	•	1	6	12	71	4	24	0	•	17	6	94
Rogue River	Jumpoff Joe Creek	•	•	•	•	•	•	9	45	5	25	6	30	0	•	20	45	55
Rogue River	Kimball Creek	•	•	1	6	6	33	6	33	•	•	5	28	0	•	18	72	28
Rogue River	Libby Creek	•	•	2	11	4	22	6	33	1	6	5	28	0	•	18	67	33
Rogue River	Trail Creek	•	•	•	•	4	22	9	50	5	28	0	0	0	•	18	72	28
Rogue River	Trail Creek	•	•	1	5	1	5	10	50	2	10	6	30	0	•	20	60	40
Rogue River	Unnamed tributary	•	•		•	•	•	1	6	1	6	1	6	13	81	16	33	67
Rogue River		•	•	•	•	•	•	4	25	10	63	2	13	0	•	16	25	75
Rogue River		6	30	2	10	1	5	2	10	•	•	9	45	0	•	20	55	45
Rogue River		•	•	•	•	•	•	6	60	2	20	2	20	0	•	10	60	40
Rogue River		1	5		•	6	30	3	15	8	40	2	10	0	•	20	50	50
Rogue River		•	•	5	26	3	16	6	32	•	•	5	26	0	•	19	74	26
Smith River	Diamond Creek	•	•		•	3	20	5	33	2	13	5	33	0	•	15	53	47
Tuttle Creek		1	13	2	25	•	•	4	50		•	1	13	0	•	8	88	13
Umpqua River	Elk Creek	•	•	•	•	•	•	5	25	14	70	1	5	0	•	20	25	75
Umpqua River	Elk Creek	•	•	•	•	•	•	8	40	10	50	2	10	0	•	20	40	60
Umpqua River	North Umpqua River	•	•	•	•	4	20	10	50	6	30	0	0	0	•	20	70	30
Umpqua River	North Umpqua River	•	•	•	•	4	21	3	16	9	47	3	16	0	•	19	37	63
Umpqua River	North Umpqua River	•	•	•	•	5	28	5	28	3	17	5	28	0	•	18	56	44
Umpqua River	Smith River	•	•	•	•	1	5	6	30	9	45	4	20	0	•	20	35	65
Umpqua River	Smith River	•	•	•	•	1	5	5	26	11	58	2	11	0	•	19	32	68
Umpqua River	South Umpqua River	•	•	•	•	5	25	8	40	1	5	6	30	0	•	20	65	35
Umpqua River	South Umpqua River	•	•	•	•	1	6	9	50	6	33	2	11	0	•	18	56	44
Umpqua River	South Umpqua River	•	•	•	•	•	•	1	5	15	79	3	16	0	•	19	5	95
Umpqua River	South Umpqua River	•	•	•	•	3	19	6	38	6	38	1	6	0	•	16	56	44
Umpqua River	South Umpqua River	•	•	3	18	7	41	4	24	1	6	2	12	0	•	17	82	18
Willamette River	Coast Fork Willamette River	•	•	•	•	3	15	7	35	5	25	5	25	0	•	20	50	50
Willamette River	Coast Fork Willamette River	•	•	1	5	6	30	6	30	5	25	2	10	0	•	20	65	35
Willamette River	McKenzie River	•	•	•	•	•	•	1	6	13	81	2	13	0	•	16	6	94
Willamette River	Middle Fork Willamette River	•	•	2	11	1	5	7	37	•	•	9	47	0	•	19	53	47
Willamette River	Middle Fork Willamette River	1	5	3	15	4	20	8	40	•	•	4	20	0	•	20	80	20
Willamette River	Middle Fork Willamette River	•	•	1	5	3	15	8	40	3	15	5	25	0	•	20	60	40
Willamette River	Middle Fork Willamette River	1	6	1	6	•	•	9	50	•	•	7	39	0	•	18	61	39
Willamette River	North Fork Santiam	•	•	•	•	8	42	7	37	3	16	1	5	0	•	19	79	21
Willamette River	South Fork Santiam	•	•	•	•	2	10	6	30	12	60	0	0	0	•	20	40	60
Willamette River	South Fork Santiam	•	•	1	5	3	16	10	53	4	21	1	5	0	•	19	74	26
Willamette River	South Fork Santiam	•	•	•	•	3	18	2	12	5	29	7	41	0	•	17	29	71
Willamette River	South Fork Santiam	•	•	•	•	•	•	8	40	1	5	11	55	0	•	20	40	60
Willamette River	South Fork Santiam	•	•	•	•	•	•	0	0	20	100	0	0	0	•	20	0	100
Willamette River		•	•	•	•	•	•	0	0	18	100	0	0	0	•	18	0	100
Winchuck River		•	•	•	•	•	•	3	15	12	60	5	25	0	•	20	15	85
Winchuck River		•	•	•	•	•	•	3	15	13	65	4	20	0	•	20	15	85
Winchuck River		•	•	•	•	5	25	5	25	6	30	4	20	0	•	20	50	50
Winchuck River		•	•	•	•			6	32	11	58	2	11	0	•	19	32	68

Appendix III. Human disturbance characteristics for primary and secondary watersheds.

"Primary" indicates watersheds which drain directly to the coast with exception for the Willamette which drains into the Columbia river. "Secondary" indicates watersheds which flow into primary watersheds. "OT" is a count of the human disturbance which did not fall into other categories. "GR"is the total grazing count for each site. "LG" is the total logging count for each site. "RD" is the total road count for each site. "RC" is the total recreation count for each site. "TR" is the total trash count for each site. "RS" is the total residences count for each site. "NA" is the total observations of no human disturbance for each site. Columns adjacent to the total counts are the relative percentage for human disturbance in each category. "Total Count" is the total count of all human disturbance categories excluding "NA".

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WATERSHED		HUMAN DISTURBANCE COUNTS AND PERCENTAGES																
PRIMARY	SECONDARY	OT	OT%	GRT	GR%	LGT	LG%	RDT	RD%	RCT	RC%	TRT	TR%	RST	RS%	NAT	NA%	TOTAL COUNT
Brush Creek		0	0	0	0	0	0	11	69	3	23	1	8	0	0	0	0	15
Chetco River		5	8	0	0	19	29	12	18	20	31	7	11	2	3	0	0	65
Chetco River		2	2	0	0	20	23	20	23	19	22	13	15	14	16	0	0	88
Chetco River		0	0	0	0	0	0	7	16	20	45	17	39	0	0	0	0	44
Chetco River	Joe Hall Creek	3	11	0	0	7	25	15	54	0	0	1	4	2	7	0	0	28
Chetco River	South Fork Chetco River	0	0	0	0	13	62	0	0	0	0	0	0	0	0	8	38	21
Coos River	South Fork Coos	21	40	17	32	0	0	9	17	2	4	3	6	1	2	0	0	53
Coquille River	East Fork Coquille River	0	0	0	0	18	41	10	23	7	16	4	9	5	11	0	0	44
Coquille River	South Fork Coquille River	0	0	0	0	5	17	10	34	6	21	1	3	1	3	6	21	29
Coquille River	South Fork Coquille River	12	15	0	0	20	25	18	22	9	11	20	25	2	2	0	0	81
Elk River		0	0	0	0	0	0	9	43	5	24	0	0	0	0	7	33	21
Elk River		1	5	0	0	0	0	1	5	0	0	2	9	0	0	18	82	22
Elk River	Panther Creek	1	7	0	0	1	7	6	43	1	7	1	7	0	0	4	29	14
Hooskanaden		2	5	8	21	8	21	4	10	0	0	7	18	0	0	10	26	39
Klamath River	Cottonwood Creek	10	32	5	16	0	0	11	35	0	0	4	13	1	3	0	0	31
Klamath River	Jenny Creek	5	10	9	19	18	38	9	19	0	0	7	15	0	0	0	0	48
Klamath River		20	47	0	0	0	0	20	47	0	0	3	7	0	0	0	0	43
Myers Creek		3	7	0	0	19	42	18	40	1	2	4	9	0	0	0	0	45
Pistol River		19	40	19	4C	0	0	0	0	8	17	1	2	0	0	0	0	47
Rogue River	Antelope Creek	1	2	10	24	9	21	11	26	0	0	3	7	8	19	0	0	42
Rogue River	Applegate River	5	10	1	2	13	26	16	32	0	0	8	16	7	14	0	0	50
Rogue River	Applegate River	2	4	2	4	17	38	10	22	9	20	5	11	0	0	0	0	45
Rogue River	Applegate River	18	22	0	0	20	25	6	7	20	25	17	21	0	0	0	0	81
Rogue River	Applegate River	2	5	0	0	13	33	1	3	16	40	4	10	3	8	1	3	40
Rogue River	Applegate River	1	2	2	5	11	26	12	29	4	10	1	2	6	14	5	12	42
Rogue River	Applegate River	15	26	0	0	12	21	20	34	0	0	11	19	0	0	0	0	58
Rogue River	Applegate River	2	5	2	5	3	7	15	36	7	17	2	5	8	19	3	7	42
Rogue River	Applegate River	5	8	0	0	6	10	20	33	1	2	18	30	10	17	0	0	60
Rogue River	Applegate River	1	2	0	0	0	0	11	24	19	41	15	33	0	0	0	0	46
Rogue River	Applegate River	5	12	6	14	1	2	10	24	2	5	12	29	1	2	5	12	42
Rogue River	Bear Creek	14	18	6	8	16	20	13	16	4	5	11	14	16	20	0	0	80
Rogue River	Bear Creek	1	3	0	0	1	3	19	49	0	0	7	18	11	28	0	0	39
Rogue River	Bear Creek	11	31	10	29	10	29	0	0	0	0	4	11	0	0	0	0	35
Rogue River	Elk Creek	18	20	3	3	20	22	20	22	4	4	16	18	8	9	0	0	89
Rogue River	Evans Creek	1	2	0	0	20	42	20	42	0	0	5	10	2	4	0	0	48
Rogue River	Graves Creek	0	0	0	0	18	60	9	30	1	3	0	0	0	0	2	7	30
Rogue River	Illinois River	1	2	1	2	16	36	11	24	0	0	5	11	10	22	1	2	45
Rogue River	Illinois River	3	4	0	0	18	22	16	20	11	14	20	25	13	16	0	0	81
Rogue River	Illinois River	0	0	0	0	0	0	4	14	4	14	4	14	0	0	16	57	28
Rogue River	Illinois River	1	3	0	0	0	0	8	24	8	24	4	12	3	9	9	27	33
Rogue River	Illinois River	1	2	3	7	17	39	1	2	12	27	5	11	4	9	1	2	44
Rogue River	Illinois River	1	5	1	5	0	0	1	5	0	0	2	10	0	0	16	76	21
Rogue River	Illinois River	1	3	0	0	20	61	10	30	0	0	2	6	0	0	0	0	33
Rogue River	Illinois River	0	0	0	0	15	41	10	27	2	5	3	8	4	11	3	8	37

WATERSHED		HUMAN DISTURBANCE COUNTS AND PERCENTAGES																
PRIMARY	SECONDARY	OT	OT%	GRT	GR%	LGT	LG%	RDT	RD%	RCT	RC%	TRT	TR%	RST	RS%	NAT	NA%	TOTAL COUNT
Rogue River	Illinois River	4	13	0	0	1	3	12	40	8	27	3	10	1	3	1	3	30
Rogue River	Illinois River	7	16	0	0	0	0	15	33	19	42	4	9	0	0	0	0	45
Rogue River	Jim Hunt Creek	3	4	0	0	20	26	14	18	20	26	16	21	5	6	0	0	78
Rogue River	Jumpoff Joe Creek	4	6	3	4	9	13	18	25	11	15	13	18	14	19	0	0	72
Rogue River	Kimball Creek	1	4	0	0	14	61	0	0	1	4	2	9	0	0	5	22	23
Rogue River	Libby Creek	16	21	0	0	20	26	16	21	5	6	20	26	0	0	0	0	77
Rogue River		2	3	0	0	20	26	20	26	20	26	13	17	1	1	0	0	76
Rogue River		0	0	0	0	0	0	0	0	2	10	0	0	0	0	18	90	20
Rogue River		0	0	0	0	0	0	10	50	9	45	1	5	0	0	0	0	20
Rogue River		0	0	0	0	0	0	0	0	20	74	7	26	0	0	0	0	27
Rogue River		1	5	0	0	0	0	0	0	3	14	0	0	0	0	17	81	21
Rogue River	Tull Creek	16	23	0	0	17	24	16	23	0	0	15	21	7	10	0	0	71
Rogue River	Tull Creek	1	2	0	0	14	33	12	29	1	2	8	19	6	14	0	0	42
Rogue River	Unnamed tributary to Rogue River	7	23	3	10	5	17	9	30	1	3	2	7	1	3	2	7	30
Smith River	Diamond Creek	0	0	0	0	0	0	3	18	2	12	1	6	0	0	11	65	17
Tuttle Creek		5	21	0	0	6	25	4	17	2	8	4	17	3	13	0	0	24
Umpqua River	Elk Creek	3	5	19	30	20	31	10	16	0	0	12	19	0	0	0	0	64
Umpqua River	Elk Creek	7	11	0	0	15	23	15	23	3	5	13	20	11	17	0	0	64
Umpqua River	North Umpqua River	20	17	20	17	20	17	0	0	19	16	20	17	21	18	0	0	120
Umpqua River	North Umpqua River	8	24	0	0	2	6	10	29	6	18	5	15	0	0	3	9	34
Umpqua River	North Umpqua River	0	0	0	0	18	41	14	32	8	18	4	9	0	0	0	0	44
Umpqua River	Smith River	1	2	6	11	20	35	20	35	5	9	5	9	0	0	0	0	57
Umpqua River	Smith River	0	0	0	0	20	57	10	29	2	6	1	3	2	6	0	0	35
Umpqua River	South Umpqua River	10	11	19	22	19	22	10	11	0	0	19	22	10	11	0	0	87
Umpqua River	South Umpqua River	8	14	0	0	0	0	14	25	7	13	17	30	10	18	0	0	56
Umpqua River	South Umpqua River	2	5	13	30	12	28	8	19	1	2	4	9	3	7	0	0	43
Umpqua River	South Umpqua River	1	2	0	0	20	43	20	43	0	0	5	11	1	2	0	0	47
Umpqua River	South Umpqua River	1	3	0	0	17	59	5	17	0	0	6	21	0	0	0	0	29
Willamette River	Coast Fork Willamette River	4	10	5	13	15	38	12	31	1	3	2	5	0	0	0	0	39
Willamette River	Coast Fork Willamette River	0	0	1	2	17	30	17	30	13	23	6	11	3	5	0	0	57
Willamette River	McKenzie River	20	20	0	0	20	20	20	20	20	20	20	20	0	0	0	0	100
Willamette River	Middle Fork Willamette River	6	15	0	0	10	25	4	10	3	8	5	13	4	10	8	20	40
Willamette River	Middle Fork Willamette River	5	16	0	0	0	0	2	6	6	19	6	19	0	0	12	39	31
Willamette River	Middle Fork Willamette River	0	0	1	2	1	2	10	24	21	51	7	17	0	0	1	2	41
Willamette River	Middle Fork Willamette River	0	0	0	0	19	66	9	31	0	0	1	3	0	0	0	0	29
Willamette River	North Fork Santiam	1	2	0	0	16	28	11	19	9	16	11	19	10	17	0	0	58
Willamette River	South Fork Santiam	0	0	12	20	11	18	18	30	11	18	4	7	4	7	1	2	61
Willamette River	South Fork Santiam	0	0	1	3	16	50	10	31	0	0	4	13	0	0	1	3	32
Willamette River	South Fork Santiam	1	2	0	0	1	2	14	33	18	42	3	7	4	9	2	5	43
Willamette River	South Fork Santiam	0	0	0	0	10	27	12	32	10	27	3	8	1	3	1	3	37
Willamette River	South Fork Santiam	0	0	0	0	0	0	20	48	20	48	2	5	0	0	0	0	42
Willamette River		19	30	0	0	20	31	4	6	2	3	19	30	0	0	0	0	64
Winchuck River		7	8	0	0	20	24	14	17	11	13	19	23	13	15	0	0	84
Winchuck River		13	16	2	3	19	24	13	16	15	19	6	8	11	14	1	1	80
Winchuck River		1	3	0	0	6	17	20	56	4	11	5	14	0	0	0	0	36
Winchuck River		1	4	0	0	0	0	10	40	8	32	0	0	0	0	6	24	25

Appendix IV. Oregon Department of Environmental Quality data: Klamath River downstream Big Bend Power Station (Storet # 41035)

pH and nutrient data collected on by the ODEQ water quality monitoring section from the time period between 23 April 1993 through 12 May 1998 as a part of the Deschutes/Klamath/Rogue ambient monitoring program

PARAMETER

Date	pH	$NH^{3+}NH^{4+}$[1] MG/L	NH_3-N[2] MG/L	$NO_2^- + NO_3^-$[3] MG/L	N-TOT[4] MG/L	PO_4^{3-}-DIS[5] MG/L	PO_4^{3-}-TOT[6] MG/L
03/23/93	7.9	0.15	0.0020	0.29	1.6	0.016	0.290
05/25/93	8.2	0.04	0.0020	0.14	0.9	0.074	0.180
07/20/93	8.1	0.03	0.0010	0.28	1.2	0.103	0.130
09/15/93	7.7	0.12	0.0020	0.61	1.0	0.071	0.120
11/02/93	8.0	0.08	0.0010	0.42	0.8	0.046	0.080
03/29/94	8.4	0.03	0.0010	0.20	0.4	0.061	0.090
05/10/94	8.6	0.07	0.0090	0.50	1.4	0.197	0.260
07/19/94	8.6	0.04	0.0050	0.21	0.6	0.098	0.120
09/27/94	8.0	0.08	0.0030	0.32	1.3	0.080	0.200
11/15/94	8.1	0.08	0.0010	0.24	0.4	0.041	0.180
01/24/95	8.1	0.17	0.0020	0.50	1.2	0.119	0.260
03/21/95	7.9	0.05	0.0006	0.11	1.0	0.021	0.220
05/09/95	8.1	0.07	0.0020	0.13	0.9	0.058	0.120
07/18/95	8.1	0.08	0.0030	0.69	0.9	0.139	0.190
09/26/95	7.7	0.31	0.0050	1.10	2.0	0.154	0.280
11/08/95	7.8	0.32	0.0030	*	1.4	0.087	0.150
01/10/96	7.8	0.46	0.0030	0.52	1.5	0.053	0.160
03/26/96	8.1	0.11	0.0020	0.21	0.9	0.044	0.110
05/14/96	8.1	0.09	0.0030	0.21	1.4	0.101	0.160
07/23/96	8.0	0.1	0.0050	0.54	1.1	0.165	0.220
09/17/96	7.8	0.22	0.0040	0.45	1.3	0.131	0.200
11/19/96	8.0	0.19	0.0030	0.57	1.2	0.069	0.120
01/29/97	7.9	0.39	0.0030	0.36	1.4	0.065	0.210
03/25/97	8.0	0.07	0.0010	0.20	0.7	0.043	0.110
05/14/97	7.9	0.1	0.0030	0.19	0.7	0.113	0.160
07/15/97	8.5	0.03	0.0030	0.24	0.5	0.079	0.090
09/15/97	8.2	0.04	0.0010	0.27	0.5	0.102	0.130
11/18/97	7.8	*	*	*	*	*	*
01/27/98	8.1	0.2	0.0010	0.44	1.5	0.014	0.200
01/27/98	8.1	0.2	0.0030	0.44	1.6	0.020	0.210
03/17/98	8.1	0.07	0.0010	0.22	1.0	0.051	0.140
05/12/98	8.2	0.04	0.0010	0.19	*	0.057	0.130

[1] Total nitrogen as ammonia

[2] Total un-ionized ammonia

[3] Total nitrogen as nitrite and nitrate

[4] Total nitrogen

[5] Dissolved phoshate

[6] Total phosphate

END

08-30-99